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Abstract

Essays on a Consumer Subsidy with Firms' Bidding

Ge Zhang

2021

This dissertation evaluates a consumer subsidy program known as "Home Appliances Going to the Countryside" (HAGC). The HAGC subsidy program provided rebates to Chinese consumers from the countryside if they purchased eligible products from 2008 to 2012.

This dissertation first investigates the relation between the HAGC subsidy program and the ownership and recent purchases of home appliances and electronics, using data from the China Health and Nutrition Survey. We find that households with agricultural Hukou made a larger number of purchases in the past 12 months than non-agricultural ones during the HAGC subsidy program, and we provide evidence that such a pattern is related to the subsidy rather than merely a trend for agricultural Hukou households.

One interesting feature of the HAGC subsidy program is that firms competed in a bidding process to make their products eligible for the subsidy. Each participating firm proposed a list of products and a price ceiling for each product. The government evaluated the proposals and determined the set of products to be eligible for the subsidy. After the competition for subsidy eligibility, the firms must set a subsidized product's price below its price ceiling. Such strategic competition for subsidy eligibility may put downward pressure on prices and play an essential role in shaping the welfare implication of the subsidy program.

Data on the HAGC-eligible cell phones and their price ceilings are assembled from government documents, then linked to the Chinese cell phone sales data. We find that products of large or local-brand firms with large previous sales are more likely to be eligible for

the subsidy while there is no clear pattern about the winning price ceilings.

This dissertation conducts structural modeling and estimation to quantify and decompose the welfare effect of the HAGC subsidy program. The demand is specified by a random-coefficients discrete-choice model that allows consumers to differ in preferences and subsidy eligibility. Given the subsidized product set and the price ceilings, firms are modeled as strategically choosing prices to maximize profits subject to the constraint that they must price a subsidized product below its price ceiling. An extension to the classic estimation procedure is developed to estimate such models with multiple consumer types and binding pricing constraints.

Counterfactual simulations show that the program increased the consumer and producer surpluses by 69% and 60% of the total government subsidy payment, respectively. In contrast, a hypothetical subsidy to the actual eligible products without price ceilings would make these ratios 62% and 64%. A hypothetical subsidy to all products without price ceilings would make these ratios 96% and 37%, but the total subsidy payment would be six times the actual payment and might not be financially feasible. These results indicate that the competition for subsidy eligibility benefited consumers and society while limiting the required government subsidy payments.

This dissertation also addresses other aspects of the program's policy implications. We find that the subsidy eligibility is negatively correlated with the post-program brand image for a high-end foreign brand, negatively with the number of competitors, and positively with a product model's age. However, it has no significant correlation with the technology upgrading to 3G or smartphone.

Essays on a Consumer Subsidy with Firms' Bidding

A Dissertation

Presented to the Faculty of the Graduate School

of

Yale University

in Candidacy for the Degree of

Doctor of Philosophy

by

Ge Zhang

Dissertation Directors: Steven Berry, Philip Haile

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Chapter 1

The HAGC Subsidy Program and Home Appliance Consumption

1.1 Introduction

Governments worldwide often use consumption subsidies or taxes — two sides of the same coin — to stimulate or discourage certain types of consumption. Examples include solar panel rebates and tobacco excise taxes. Consumption subsidies often also aim to help targeted disadvantaged consumers (e.g., food stamps, child-care subsidies) and constitute a major component of government expenditure.

This dissertation conducts an empirical study on a consumer subsidy program known as "Home Appliances Going to the Countryside" (henceforth, HAGC). Implemented in China from 2008 to 2012, it provided a rebate of up to 13% to consumers from the countryside if they purchased eligible home appliances and electronics. By the end of 2012, the HAGC program subsidized 298 million units of products sold for a total of 720.5

billion CNY.[1] The total government subsidy spending was around 90 billion CNY.

In the HAGC subsidy program, firms must compete to make their products eligible for the subsidy. Such competition might motivate firms to lower prices and improve consumer surplus. Specifically, the program included a bidding process where each participating firm proposed a list of products and a price ceiling for each product. The government evaluated the proposals and determined the set of products to be eligible for the consumer subsidy. It was common knowledge that the price ceiling was a crucial determinant of a product's chance to become eligible. After the bidding, the firms must set a subsidized product's retail price below its price ceiling. To increase the probability of becoming eligible for the subsidy, a firm might have an incentive to commit to a low price ceiling. Thus, the ex-ante competition for subsidy eligibility might put downward pressure on prices, mitigating the price increase that would otherwise result from the consumer subsidy.

In this chapter, we first provide background information on the HAGC subsidy program. We emphasize the HAGC policy variations across the years, provinces, and product categories. We also discuss the consumers' subsidy eligibility depending on the so-called "Hukou" household registration type, the difference between the household registration type and the rural/urban residence location type, and why we shall distinguish these two kinds of consumer types.

Using data from the waves in the years 2006, 2009, 2011, and 2015 of the China Health and Nutrition Survey (henceforth, CHNS), we investigate home appliance ownership and its relation to the HAGC subsidy program. We see that rural households with agricultural Hukou had lower average ownership of home appliances than households with other Hukou and residence types, but their ownership increased the most over the years in our data.

[1]CNY is short for the Chinese Yuan, the local currency in the People's Republic of China.

The regression analyses indicate that households with agricultural Hukou had lower stock measures of home appliance ownership (i.e., whether the household owns a certain product, the number of this product owned, the total value of this product). However, they had a higher flow measure as the number of this product purchased in the past 12 months. Such a pattern holds for various HAGC-eligible product categories and sub-samples and cannot be explained by the time trend of home appliance consumption. Using the policy variations for a provincial product category of the HAGC subsidy program, we distinguish consumers' subsidy eligibility from agricultural Hukou, and we show that the HAGC subsidy program is significantly positively associated with home appliance consumption.

This chapter is related to the rich literature in development and labor economics on program evaluation, especially for subsidies and other social benefit programs in developing countries. The most relevant to this dissertation are the studies of the HAGC subsidy program. For example, Chen et al. (2015) exploit the variations in the home appliance adoption due to the HAGC program and estimate the causal effects of household technology on health outcomes by difference-in-differences and instrumental variable approaches. Their primary findings include that the increasing use of household technology induced by HAGC raises the probability of being obese and the incidence of being sick or injured for rural women but has no impact on rural men. Tewari and Wang (2020) look into the causal effect of labor-saving household technologies on female labor force participation. They find that females rather than males drive the time reallocation in households, and females with primary-only education are most likely to enter the labor market due to adopting appliances and reducing housework.

Like these papers, we investigate a subsidy program that aims to help disadvantaged consumers. Unlike most of these papers, we quantify the direct impacts of the subsidy program on consumption and welfare rather than the indirect impacts on socioeconomic outcomes. In our study of these direct impacts, we carefully distinguish the rural/urban

residence location type and the agricultural/non-agricultural Hukou household registration type, unlike Chen et al. (2015) exclusively relying on the former and Tewari and Wang (2020) on the latter. To the best of our knowledge, we are the first to link a data set of price ceilings in the HAGC subsidy program to market sales data (see Chapter 2) and to investigate the welfare effect of firms' competition for subsidy eligibility in HAGC (in Chapter 3).

We leave the analyses related to the firms' subsidy eligibility competition for the next two chapters, with a focus on the cell phone category of the HAGC subsidy program. Specifically, Chapter 2 investigates the equilibrium outcomes of the bidding process in the HAGC subsidy program as well as the policy implications on post-program sales trends, market structures, new product models, and technology upgrading. Chapter 3 quantifies the welfare effect of the HAGC program on firms and different types of consumers and further decomposes the overall welfare effect into those of the subsidy itself, the set of eligible products, and the price ceilings.

The remainder of this chapter proceeds as follows. Sections 1.2 to 1.4 provide the background of the HAGC subsidy program, especially the policy variations and consumer eligibility. Section 1.5 describes the CHNS data used in this chapter. Section 1.6 analyzes home appliance ownership and recent purchases during the HAGC subsidy program.

1.2 An Overview of HAGC

"Home Appliances Going to the Countryside" (HAGC) was a subsidy program roughly in 2008-2012 funded by the Chinese government. This program provided subsidies to targeted consumers if they purchased eligible home appliances and electronics, such as color TVs, refrigerators, washing machines, and cell phones. The main goals were to improve the quality of life for the relatively low-income rural population and stimulate domestic consumption when China's exports declined severely due to the 2008 financial crisis.

The HAGC subsidy program spent a huge fund on the subsidy payment and enormously boosted the sales of products in the subsidized categories. According to the Ministry of Commerce of China, the HAGC subsidy program made a total government spending of 90 billion CNY on 298 million units of subsidized products sold for 720.5 billion CNY by the end of 2012.

Only the winning products in a bidding process were eligible for the subsidy. Each eligible product model was subject to a price ceiling (proposed by the firm), where the price ceiling must be no larger than the upper price limit of the corresponding product category (set by the government). The upper price limit of each product category was relaxed in 2010 but constant over time and provinces otherwise.[2]

The subsidy was in the form of a rebate. If a consumer was eligible for the subsidy[3] and purchased a qualified product, she paid the same retail price as ineligible consumers but would receive a rebate in proportion to the retail price up to a maximum rebate amount. The rebate rate was constant at 13% over time, provinces, and product categories. The maximum rebate amount was equal to 13% times the upper price limit before 2010 of the corresponding product category.

The consumers were very likely to be aware of both the eligible products and the effective prices after the rebate. The HAGC program was one of the most important subsidy policies in China around 2010, the public media widely and repeatedly reported the HAGC program and the eligible products, and there was one HAGC label on the package of each eligible product.

[2]See Section 2.2 for more information on the bidding and the price ceilings, and Section 1.3 for the upper price limits.

[3]See Section 1.4 for more information on the consumer eligibility.

1.3 Policy Variations and Product Categories

The HAGC program was first launched in December 2007 as a pilot program in three provinces[4], was expanded to twelve more provinces[5] in November 2008, and eventually to all the other provinces[6] in mainland China in January 2009. It was first terminated in the three pilot provinces in December 2011, in the next twelve provinces in November 2011, and then in all the remaining provinces in January 2013. The different ending times ensured that people in each province were eligible for the subsidy for the same length of time.

There were independent rounds of bidding and subsidy across years and province groups. On the one hand, the thirty-one provinces in mainland China were divided into the three groups mentioned above. On the other hand, the bidding results were announced around the beginning of each year, and the subsidy was in effect immediately until approximately one year later. There were one round only for the first province group in 2008, one round for the first and second groups and another for the third in 2009, one nationwide round in 2010, another nationwide round in 2011, and one round only for the second and third groups in 2012. Such variations in the subsidy policy across time and provinces help identify consumer preferences and marginal costs in Chapter 3.

Table 1.1 summarizes the product categories of the HAGC subsidy program, whether this category was eligible for the subsidy nationwide or only in selected provinces, the year that this category became eligible for the subsidy, the upper price limit before 2010, and the relaxed limit since 2010. Four categories of products were subsidized nationwide, including color TVs, refrigerators, and cell phones since the beginning of the pilot program,

[4]The first group of provinces includes Henan, Shandong, and Sichuan.

[5]The second group of provinces includes Anhui, Chongqing, Guangxi, Heilongjiang, Hubei, Hunan, Inner Mongolia, Liaoning, and Shaanxi.

[6]The third group of provinces includes Beijing, Fujian, Gansu, Guangdong, Guizhou, Hainan, Hebei, Jiangsu, Jiangxi, Jilin, Ningxia, Qinghai, Shanghai, Shanxi, Tianjin, Tibet, Xinjiang, Yunnan, and Zhejiang.

and washing machines added in 2009. Each province was allowed to choose two additional product categories among air conditioners, water heaters, computers, microwave ovens, and electromagnetic cookers to be subsidized since 2009, and one more product category among electric cooking pots, instant pots, kitchen ventilators, gas stoves, DVD players, and electric bikes to be subsidized since 2010. The provincial product categories brought additional policy variations of the HAGC subsidy program across provinces and years.

Table 1.1: Product Categories of the HAGC Subsidy Program

Product Category	Nationwide?	Started in	Price Limit (CNY)	
			before 2010	since 2010
Color TVs	Yes	2008	3,500	7,000
Refrigerators	Yes	2008	2,500	4,000
Cell phones	Yes	2008	1,000	2,000
Washers	Yes	2009	2,000	3,500
Wall-mounted air conditioners	No	2009	2,500	3,500
Floor-standing air conditioners	No	2009	4,000	6,000
Computers	No	2009	3,500	5,000
Electromagnetic cookers	No	2009	600	1,000
Microwave ovens	No	2009	1,000	1,500
Solar water heaters	No	2009	4,000	5,000
Storage water heaters	No	2009	1,500	2,500
Gas water heaters	No	2009	2,500	3,500
Kitchen ventilators	No	2010	N/A	2,600
Electric bikes	No	2010	N/A	2,000
DVD players	No	2010	N/A	500
Electric cooking pots	No	2010	N/A	500
Gas stoves	No	2010	N/A	1,500
Instant pots	No	2010	N/A	600

1.4 Consumer Eligibility and Hukou

The population data set described in Section 1.4 is an essential component of the joint work in Chapter 3 with Ying Fan.

Roughly 0.9 billion Chinese citizens, or 70% of the national population, were eligible for

the HAGC subsidy. A consumer was eligible if and only if she had a so-called "Agricultural Hukou". Hukou is a household registration system used in mainland China, and the household register is issued per family. Historically, Hukou officially identified a person as a permanent resident of an area: agricultural Hukou meant permanent residence in a rural area, and non-agricultural Hukou meant permanent residence in an urban area. However, due to rapid urbanization and massive migration within China, Hokou was no longer a good description of whether a person mostly lived and worked in a rural or urban area by the time of the HAGC program (as shown in Figure 1.1).

We can see the difference between residence location and Hukou from the data on demographics from the National Bureau of Statistics of China (NBS).[7] The NBS provides the data on rural and urban residents each year and province, but not Hukou type. One exception is that in the 2010 Population Census, the NBS provides the provincial-level data on four types of people: rural residents with agricultural Hukou, urban residents with agricultural Hukou, rural residents with non-agricultural Hukou, and urban residents with non-agricultural Hukou. Using these data from the 2010 Census, we compute the conditional proportions Pr(agriculture Hukou | urban residents) and Pr(agriculture Hukou | rural residents). We combine these province-level conditional proportions with province/year-level data on the numbers of rural and urban residents to obtain the (approximation of) populations of all four types in each province and each year.[8]

Figure 1.1 shows the distribution of population proportions across "markets", combinations of a province and a quarter. Each of the four panels corresponds to a combination of a residence type (rural or urban) and a Hukou type (agriculture or non-agriculture). For the same market, the four percentages in the four panels add up to 100%.[9] From

[7]https://data.stats.gov.cn/english/

[8]We assume that these conditional proportions did not change during the time of the data.

[9]For example, in the Heilongjiang province in 2010, 40% of the total population were people with agricultural Hukou in rural locations, 5% for agricultural Hukou in urban, 10% for non-agricultural

the upper right panel, we can see many markets with a sizable proportion of consumers living and working in an urban area while being registered as agricultural Hukou. From the figure, we can also see the significant variation in residence and Hukou proportions across markets.

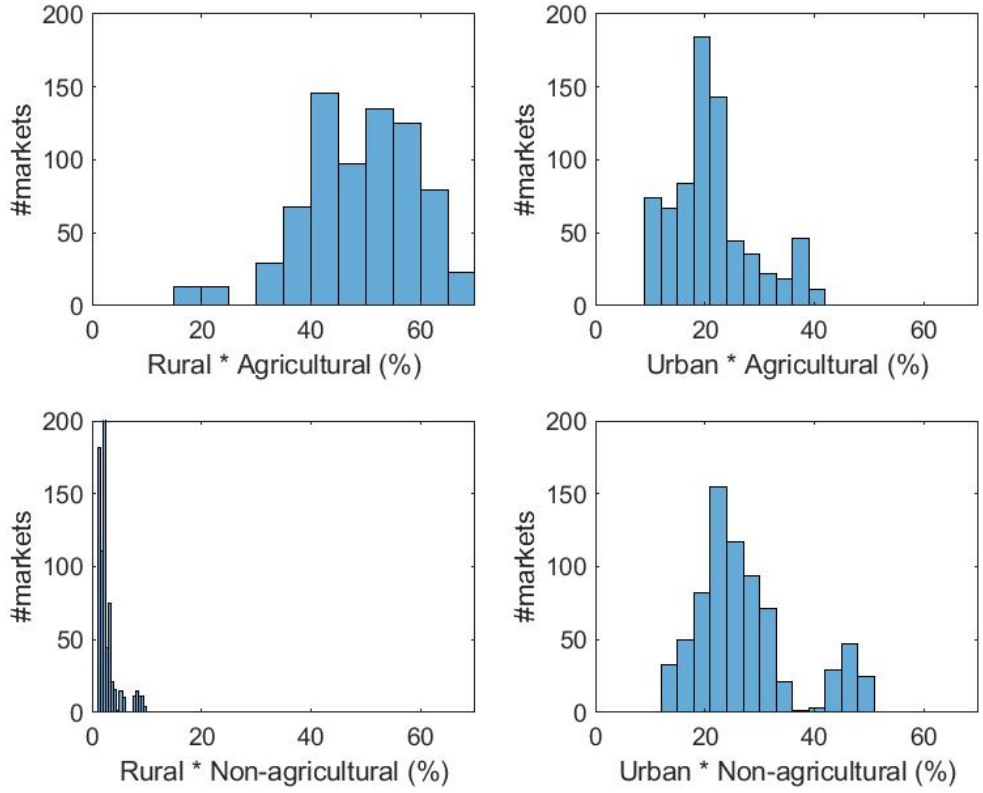


Figure 1.1: Population Proportions by Hukou and Residence Location

Traditionally, the Chinese government often assigns social benefits based on agricultural or non-agricultural Hukou status (Wang 2014). One reason is that the government has the official record of Hukou information for every citizen in mainland China. When the government implements a social benefit program, it is much less time- and labor-consuming to verify Hukou status than income level and residence location. Another reason is that the Hukou registration type (agriculture/non-agriculture) was given to a person at her birth based on her parents' Hukou types, and it is prohibitively difficult and costly to change in the short run. Assigning benefits based on Hukou helps prevent people

Hukou in rural, and the rest 45% for non-agricultural Hukou in urban.

from abusing benefits by taking actions to become eligible for social programs. Due to these two reasons, the HAGC subsidy program used agriculture Hukou as the eligibility criterion for simplicity despite the aim to help low-income residents in the countryside, and it is reasonable for us to assume that consumers did not change Hukou types in response to the HAGC program.

Over the past few decades since the economic reform in 1978, the Chinese government has taken steps to reform the Hukou system in response to a changing economic system. Accordingly, the National Bureau of Statistics of China does not release Hukou populations each year and province unless in the national population census such as the one in 2010. As some precise and up-to-date data on residence location became available since the launch of high-quality household surveys such as *China Family Panel Studies*[10] and *China Health and Retirement Longitudinal Study*[11] around 2010, an increasing number of studies emphasize the difference between rural and urban residents instead of merely between Hukou types.[12]

Given the difference between Hukou and residence and the difference between rural and urban residents, we distinguish agriculture/non-agriculture Hukou and rural/urban residence in our analysis. While the former distinction (agriculture vs. non-agriculture) determines the subsidy eligibility, the latter (rural vs. urban residents, or population in a rural vs. urban area) is assumed to be relevant for consumer preferences in the demand model of Chapter 3. The significant variation in residence and Hukou proportions across markets helps identify our demand model.

[10]https://opendata.pku.edu.cn/dataverse/CFPS?language=en

[11]http://charls.pku.edu.cn/index/en.html

[12]A few examples can be found at http://charls.pku.edu.cn/pages/publications/111/en.html.

1.5 Data

The data used in this chapter come from the China Health and Nutrition Survey (CHNS)[13], and our observations are at the household/year level. Three features of CHNS make it suitable for our analysis of the home appliance consumption under the HAGC subsidy program.

First and foremost, CHNS collects detailed information on home appliances in each surveyed household. It has specific questions for many different categories of products, including but not limited to color TVs, refrigerators, washing machines, and cell phones — the four nationwide categories of the HAGC subsidy program. It not only asks whether the household owns a certain product as many other surveys do, but also follows up about the number of this product owned, the total value of this product owned, and, most importantly, the number of this product purchased in the past 12 months. CHNS also provides supplemental information about the HAGC subsidy eligibility and home appliance consumption, such as Hukou type, residence location type, household income, and household size.

Second, CHNS has several waves of surveys before, during, and after the HAGC subsidy program, allowing comparisons across time. The two waves in 2009 and 2011 were conducted when the HAGC subsidy of the four nationwide categories was in effect in every mainland province. There were another two waves used in our analysis, one in 2006 before the earliest pilot program of HAGC, and one in 2015 when the HAGC subsidy program had ended in all mainland provinces.

Third, CHNS has good coverage of provinces for our analysis of the HAGC program (though not covering all mainland provinces or being national representative). The households surveyed by CHNS between 2006 and 2015 include those from Henan and Shandong in the first HAGC pilot group of provinces, from Chongqing, Guangxi, Hei-

[13]https://www.cpc.unc.edu/projects/china

longjiang, Hubei, Hunan, Liaoning in the second HAGC province group, and from Beijing, Guizhou, Jiangsu, Shanghai in the third group. Moreover, there were policy variations across the CHNS provinces and years about whether a specific provincial product category was subsidized. Such variation can distinguish the effect of the HAGC subsidy program from the fixed effect of agricultural Hukou population (e.g., Table 1.8 in Section 1.6).

Table 1.2 summarizes one ownership measure in each of the first four panels. The four measures for the same product category are typically in line with each other, and more households owned color TVs and cell phones than refrigerators and washers. Panel V of Table 1.2 describes the demographic variables, where "rural" refers to residing in a rural area and "agricultural" means the household had a member with agricultural Hukou and was eligible for the nationwide HAGC subsidy categories in 2009 and 2011. As the interaction of "rural" and "agricultural" shows, there is a fairly large but far from the perfect overlap between rural residence and agricultural Hukou. There are 20,788 household/year level observations in our sample, and the missing values are not a serious concern for most variables.[14] We do not list the number of observations by province or year to save space, but the observations are roughly evenly distributed across the provinces and years.

Figure 1.2 explores the variations in the "yes or no" ownership (i.e., Yes: 1; No: 0) of the four nationwide product categories of HAGC, one in each sub-figure. The percentage stands for the proportion of households that owned the product. We show the differences across the four Hukou/residence groups of households[15] and the changes over survey years. The average ownership increased over the years for almost all household groups

[14]The only exception is the log of the total value of products. This variable is missing for around half of the observations for each product category. Such missing is because the interviewee was asked to provide an estimate of the value (to the best of her knowledge), and the interviewee was often not the household member who made the purchases.

[15]"Ag" is short for agricultural Hukou and "Non-ag" for non-agricultural Hukou.

Table 1.2: Summary Statistics of Ownership Measures and Demographics

Variable	(1) Mean	(2) Std.	(3) Min	(4) Max	(5) Obs.
Panel I. Owned this product? (Yes: 1; No: 0)					
Color TV	0.96				20,756
Refrigerator	0.72				20,753
Washer	0.77				20,753
Cell phone	0.80				20,752
Panel II. Number of products owned					
Color TV	1.30	0.76	0	9	20,721
Refrigerator	0.77	0.55	0	9	20,702
Washer	0.81	0.54	0	9	20,704
Cell phone	1.63	1.26	0	9	20,712
Panel III. Log of total value of products in CNY					
Color TV	7.05	1.05	2.30	11.51	13,676
Refrigerator	7.06	0.79	0.00	11.51	9,336
Washer	6.36	0.95	0.00	11.51	10,393
Cell phone	6.84	1.04	0.00	11.08	10,771
Panel IV. Number of products purchased last 12 months					
Color TV	0.10	0.35	0	9	20,130
Refrigerator	0.06	0.25	0	9	20,232
Washer	0.06	0.24	0	5	20,186
Cell phone	0.17	0.49	0	6	20,174
Panel V. Demographics					
Agricultural	0.59				20,703
Rural	0.63				20,788
Agricultural*Rural	0.48				20,703
Household size	3.26	1.44	1	7	20,334
Log(HH. income per capita)	8.82	1.76	0.00	14.00	20,334

Observations are on the household/year level. Variables without standard deviation, min, or max are 0-1 dummies. All the negative values of log variables have been replaced by zero.

and products. The rural households with agricultural Hukou, the most disadvantaged group, started from the lowest average ownership, but their ownership increased the most over the years. Urban households with non-agricultural Hukou were at the opposite extreme. Note that we need more careful analyses before we can conclude the effect of the HAGC subsidy program because the general time trend (independent of the HAGC subsidy program) of owning these products may be different across household groups, and the HAGC subsidy program included some periods during 2006-2009 and 2011-2015.

Figure 1.3 shows the same charts as Figure 1.2 but for the average number of purchases made by the household in the past 12 months. While the "yes or no" ownership is a stock measure of home appliances in the household, the number of recent purchases reflects the flow of incremental ownership. The patterns of the recent purchases in Figure 1.3 are very different from those in Figure 1.2, so we address both the stock and flow measures of ownership in Section 1.6. In general, urban households with agricultural Hukou made a larger average number of recent purchases during the HAGC subsidy program than any other household group. This result makes sense because they had a higher average income from an urban area than rural households, were eligible for the HAGC subsidy program with their agricultural Hukou, and did not have stock ownership as high as urban households with non-agricultural Hukou. In contrast, rural households with agricultural Hukou did not make much more purchases than other groups except for refrigerators despite their eligibility for the HAGC subsidy program and their high growth in the "yes or no" ownership during the period. This result suggests that many rural households with agricultural Hukou made their first-ever purchase of the product during the HAGC subsidy program but not many additional purchases after the first.

1.6 Ownership and Recent Purchases during HAGC

This section studies the relation between the HAGC subsidy program and home appliance ownership measures. Our analysis is based on the household/year level observations in

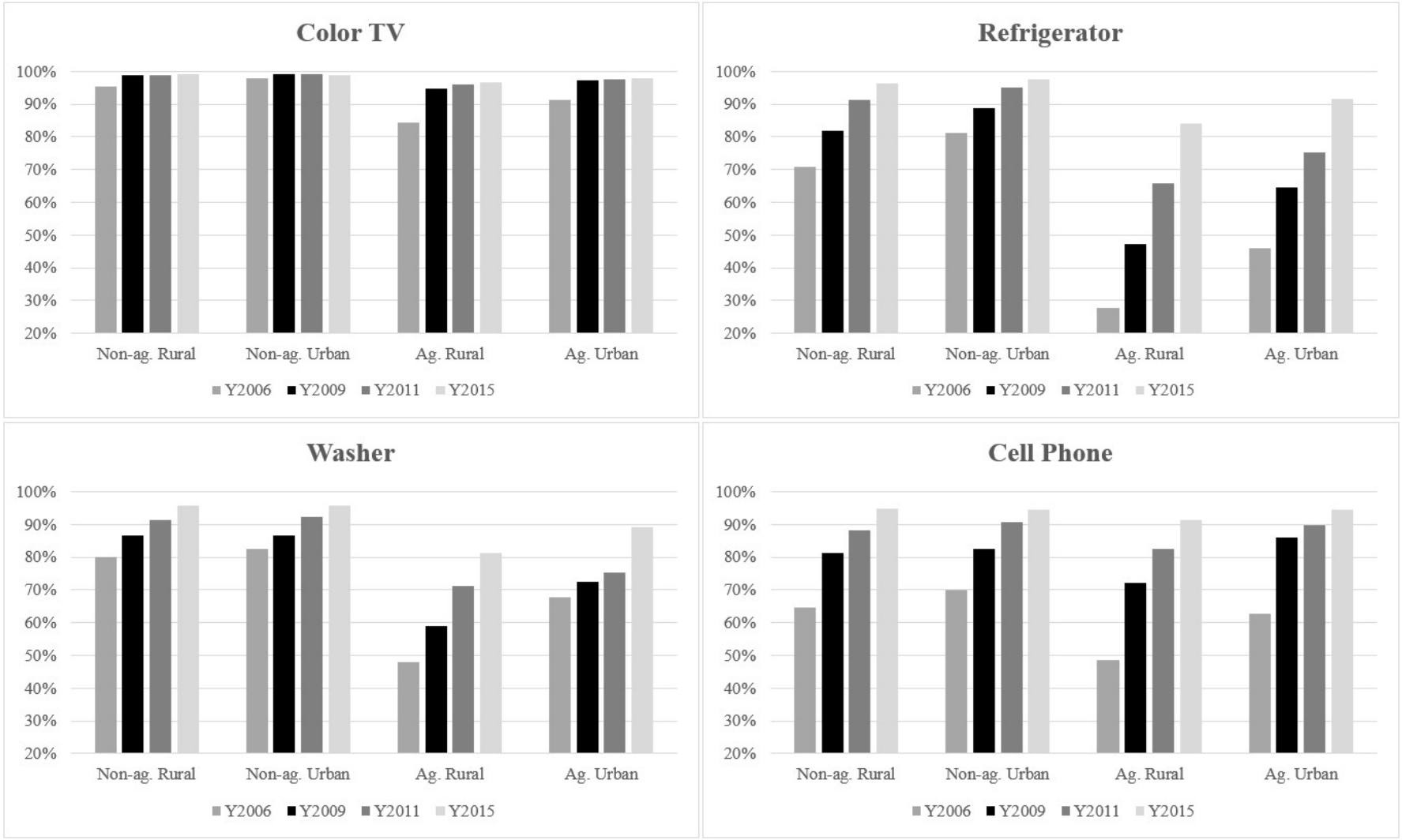
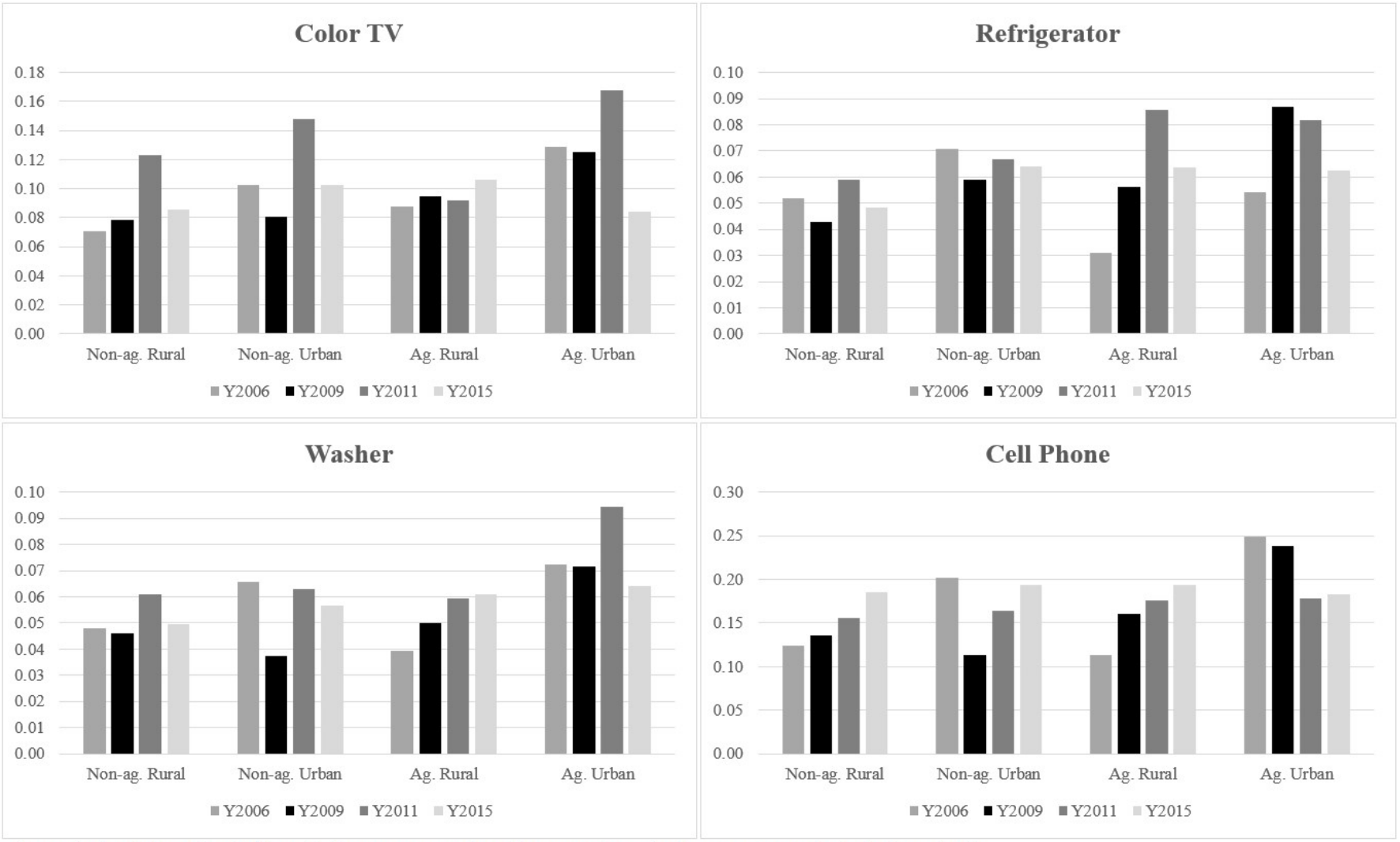


Figure 1.2: Home Appliance Ownership Over Time by Hukou and Residence Location



The vertical axis in each sub-figure is the average number of new purchases in the past 12 months in the household.

Figure 1.3: Home Appliance Purchases Over Time by Hukou and Residence Location

the survey years 2009 and 2011 unless otherwise noted.

Table 1.3 presents the regression results of four ownership measures, one in each panel. Each column within a panel is a separate regression of the ownership measure for color TVs, refrigerators, washers, or cell phones, respectively. Panel I presents the logit regressions of the "yes or no" ownership dummies, and the other panels present OLS linear regression results. The regressors include the dummy for agricultural Hukou (and thus the subsidy eligibility), that for rural residence, their interaction, and other control variables. We find that all the ownership measures for all products are lower in rural areas than in urban ones on average, and the differences are sometimes significant. The stock measures (i.e., whether the household owns a certain product, the number of this product owned, the total value of this product owned) are (sometimes significantly) lower for agricultural Hukou holders. However, the flow measure (i.e., the number of this product purchased in the past 12 months) of all product categories are significantly higher for agricultural Hukou holders, especially in urban areas. Such a contrast suggests that households with agricultural Hukou were catching up in ownership by making more recent purchases than non-agricultural ones during the HAGC subsidy program.

The patterns observed in Table 1.3 also hold for other measures and samples. For example, most home appliances are often purchased and used at the household level while cell phones are more likely to be used by a single member in the household, so we calculate and run regressions for the *per capita* number, value, and recent purchase of cell phones, as shown in Table 1.4. Again, we see that households with agricultural Hukou are significantly lower in stock measures but higher in the recent purchase flow measure.

As another example, we construct a panel of the households surveyed in both the 2009 and 2011 waves of CHNS. We calculate the change in the number of products owned by the household between the two years. Table 1.5, again, shows that agricultural Hukou is associated with a larger increase in the number of products owned by the household, and

Table 1.3: Regressions of Ownership Measures

	(1) Color TV	(2) Refrigerator	(3) Washer	(4) Cell phone
Panel I. Owned this product? (Yes: 1; No: 0)				
Agricultural	-1.36**	-1.53**	-1.31**	-0.19
	(0.32)	(0.11)	(0.11)	(0.13)
Rural	-0.41	-0.50**	-0.07	-0.23*
	(0.34)	(0.12)	(0.11)	(0.11)
Agricultural*Rural	-0.13	-0.28*	-0.46**	-0.59**
	(0.41)	(0.14)	(0.14)	(0.16)
#Observations	10,230	10,230	10,230	10,230
Panel II. Number of products owned				
Agricultural	-0.03	-0.14**	-0.13**	-0.01
	(0.02)	(0.02)	(0.02)	(0.04)
Rural	-0.01	-0.02	-0.02	-0.14**
	(0.02)	(0.01)	(0.01)	(0.03)
Agricultural*Rural	-0.14**	-0.16**	-0.13**	-0.31**
	(0.03)	(0.02)	(0.02)	(0.05)
#Observations	10,207	10,193	10,193	10,199
Panel III. Log of total value of products in CNY				
Agricultural	-0.20**	-0.03	-0.04	-0.19**
	(0.04)	(0.04)	(0.04)	(0.04)
Rural	-0.22**	-0.12**	-0.17**	-0.21**
	(0.03)	(0.03)	(0.03)	(0.03)
Agricultural*Rural	-0.17**	0.03	-0.22**	-0.14**
	(0.05)	(0.04)	(0.05)	(0.05)
#Observations	9,629	7,147	7,564	8,180
Panel IV. Number of products purchased last 12 months				
Agricultural	0.06**	0.03**	0.04**	0.05**
	(0.01)	(0.01)	(0.01)	(0.02)
Rural	-0.01	-0.01	0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.02)
Agricultural*Rural	-0.07**	-0.01	-0.04**	-0.04*
	(0.02)	(0.01)	(0.01)	(0.02)
#Observations	9,803	9,843	9,823	9,793

** $p<0.01$, * $p<0.05$. Standard errors in parentheses. Observations are on the household/year level. Each column within a panel is one regression. Panel I reports the coefficients of logits (log odds), and the other panels are OLS. All regressions also control for log household income per capita, household size as categorical variables, province dummies, and survey year dummies.

the association is significant for washers and cell phones.

Table 1.4: Regressions of Per Capita Ownership Measures for Cell Phones

	(1) #Owned	(2) log(Value)	(3) #Purchase
Agricultural	-0.05**	-0.63***	0.02**
	(0.01)	(0.04)	(0.01)
Rural	-0.06**	-0.29**	0.00
	(0.01)	(0.03)	0.00
Agricultural*Rural	-0.08**	0.14**	-0.02*
	(0.02)	(0.05)	(0.01)
#Observations	10,199	8,180	9,793

** p<0.01, * p<0.05. Standard errors in parentheses. The dependent variable names are abbreviated to save space, and please refer to Table 1.3 for the complete variable names. Observations are on the household/year level. All regressions also control for log household income per capita, survey year dummies, and province dummies.

Table 1.5: Regressions of the Change in the Number of Products Owned

	(1) Color TV	(2) Refrigerator	(3) Washer	(4) Cell phone
Agricultural	0.05	0.07	0.07*	0.09*
	(0.07)	(0.04)	(0.03)	(0.03)
Rural	0.05	-0.03	0.04	-0.04
	(0.06)	(0.03)	(0.03)	(0.03)
Agricultural*Rural	0.05	0.01	0.01	-0.01
	(0.09)	(0.05)	(0.04)	(0.04)
#Observations	3,935	3,944	3,931	3,932

** p<0.01, * p<0.05. Standard errors in parentheses. The difference is calculated between 2009 and 2011 for the same household. Observations are on the household level. All regressions also control for log household income per capita, household size as categorical variables, and province dummies.

Keep in mind that the positive association between recent purchases and agricultural Hukou suggests but does not necessarily indicate that the HAGC subsidy program increased the home appliance consumption of eligible households. Agricultural Hukou holders might have made more recent purchases than non-agricultural ones even if without the HAGC subsidy program. We address this issue by the following three tables.

We run the same regressions of the number of purchases in the past 12 months as in Tables 1.3 and 1.4, but using the survey data in 2006 (Table 1.6) and those in 2015 (Table 1.7). We do not observe any significant positive correlation between recent purchases and agricultural Hukou for any product in 2006 or 2015. In other words, there is no evidence that agricultural Hukou holders made more purchases than non-agricultural ones before and after the HAGC subsidy program. This result casts doubt on the guess that agricultural Hukou holders might have made more recent purchases than non-agricultural ones even without the HAGC subsidy in 2009 and 2011.

We can also exploit the variations in provincial product categories of the HAGC subsidy program. For example, electric cooking pots were subsidized in Heilongjiang in the 12 months before the 2011 wave of CHNS, but not in other provinces or other survey waves in CHNS. Such a policy variation allows us to distinguish the pot subsidy eligibility from agricultural Hukou, the province fixed effects, and the survey year fixed effects. Table 1.8 shows that being eligible for the HAGC subsidy is significantly associated with more recent purchases of electric cooking pots with or without controlling for agricultural Hukou. This result suggests that the larger numbers of recent purchases by agricultural Hukou households observed in the previous tables may be related to the HAGC subsidy program itself rather than merely a trend for the households with agricultural Hukou.[16]

[16]There existed timing differences across provinces for a nationwide category, while our data do not include the purchases made when the subsidy was already in effect in some provinces but not others.

Table 1.6: Regressions of Recent Purchases in 2006

	(1) Color TV	(2) Refrigerator	(3) Washer	(4) Cell phone	(5) Cell phone (per capita)
Agricultural	0.03	0.02	-0.01	0.00	0.00
	(0.03)	(0.02)	(0.01)	(0.01)	(0.01)
Rural	-0.09**	-0.04*	-0.02	-0.02	-0.03**
	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
Agricultural*Rural	-0.04	-0.01	0.00	-0.01	0.00
	(0.03)	(0.02)	(0.02)	(0.02)	(0.01)
#Observations	4,254	4,208	4,268	4,239	4,254

** p<0.01, * p<0.05. Standard errors in parentheses. Observations are on the household level. All regressions also control for log household income per capita, household size as categorical variables, and province dummies.

Table 1.7: Regressions of Recent Purchases in 2011

	(1) Color TV	(2) Refrigerator	(3) Washer	(4) Cell phone	(5) Cell phone (per capita)
Agricultural	-0.05	-0.02	-0.01	0.00	-0.02*
	(0.03)	(0.02)	(0.01)	(0.01)	(0.01)
Rural	-0.03	-0.02	-0.02	-0.01	-0.01
	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
Agricultural*Rural	0.05	0.04	0.02	0.01	0.01
	(0.03)	(0.02)	(0.02)	(0.01)	(0.01)
#Observations	5,679	5,678	5,675	5,677	5,679

** p<0.01, * p<0.05. Standard errors in parentheses. Observations are on the household level. All regressions also control for log household income per capita, household size as categorical variables, and province dummies.

Table 1.8: Regressions of Recent Purchases of Electric Cooking Pots

	(1)	(2)
Eligible for pot subsidy	0.04*	0.04**
	(0.02)	(0.01)
Agricultural		0.03
		(0.02)
Rural	-0.01	0.00
	(0.01)	(0.01)
Agricultural*Rural		-0.03*
		(0.01)
#Observations	9,758	9,758

** p<0.01, * p<0.05. Standard errors in parentheses. A household is "eligible for pot subsidy" if it has an agricultural Hukou in Heilongjiang province in 2011. Observations are on the household level. All regressions also control for log household income per capita, household size as categorical variables, survey year dummies, and province dummies.

Chapter 2

The Firms' Bidding and the Market Outcomes of HAGC

It is essential to understand how the bidding process of the HAGC subsidy program was implemented before we can quantify and decompose the welfare effect of the HAGC subsidy program using structural methods in Chapter 3 (or make any solid analysis). This chapter introduces the rules of firms' bidding in the HAGC subsidy program and investigates the HAGC bidding results. We address the characteristics of the firms, products, and price ceilings that were winners in the bidding process of the HAGC program and thus became eligible for the subsidy.[1] We also address which HAGC-eligible observations (i.e., province/time/product combinations) turned out to have binding price ceilings.

This chapter also provides a big picture of the HAGC subsidy program's implications on the Chinese market. We investigate how sales changed after the HAGC subsidy program, the relation between the HAGC subsidy coverage and market entry, and the product

[1]We will not analyze in which provinces the winning firms were eligible because most winning firms were eligible for almost all the provinces in the corresponding round of bidding unless the firm did not operate or had few customer services in the province.

"age" and technology upgrading during the HAGC subsidy program. Such analyses complement our study of the bidding results (Section 2.5) and the pricing competition under the HAGC subsidy program (Chapter 3).

We focus on the cell phone category in this and the next chapters for three reasons. First, the cell phone category was one of the four categories available in all provinces, for which we have richer data than the regional product categories. As explained in Section 2.2, the set of products eligible for the subsidy was determined by a bidding process, and there were six rounds of bidding from 2008 to 2012. Combined with the various program launch and termination times across provinces mentioned in Section 1.3, they generate cross-sectional and temporal policy variations.

Second, we are able to precisely measure the effective price after the applicable subsidy in the cell phone market. On the one hand, there exist high-quality province/month-level universal sales data with detailed product characteristics for the cell phone market. On the other hand, there were concurrent additional subsidy programs for the other three national categories, but not for cell phones. For example, there was a trade-in promotion in 2009-2011, then a subsidy for energy-saving products in 2012-2013, and their documentation was not as clear and detailed as that of the HAGC subsidy program.

Third, most HAGC-eligible purchases were not for resale. People may be concerned that someone might abuse the HAGC subsidy by paying an eligible consumer for making a purchase at the subsidized price under the eligible consumer's name. While this might be a non-negligible problem for relatively valuable product categories such as color TVs, refrigerators, washing machines, the subsidy amount in the cell phone category was always no larger than 130 CNY[2], which is a small amount of money and thus not likely to motivate the violation of program rules and laws.

[2]130 CNY is about 18 US dollar based on the exchange rate at the beginning of the HAGC program

We assemble a data set on the HAGC-eligible cell phones and their price ceilings from government documents, then link it to the data on product characteristics and Chinese cell phone sales from July 2007 to June 2013, covering the two quarters before the HAGC program and the two after it. We describe the linked data and show that the HAGC subsidy program focused on the relatively low-end products sold below 2,000 CNY. These facts also guide our sample choice and structural modeling of heterogeneous demand in Chapter 3.

Note that we only observe the winning proposals but unfortunately not the confidential losing ones. In other words, we do not observe the suppliers that participated in the bidding but had no winning product; for a supplier that had at least one winning product, we do not observe whether this supplier had bid for other products, and if so, what the proposed price ceilings were.

As a result, we do not conduct a structural estimation of firms' bidding strategies, the government's evaluation criteria, or firms' (endogenous) product portfolio choices in response to the HAGC subsidy program. All the following results and discussions in this chapter are descriptions of the equilibrium outcomes, and they reveal partial correlations rather than make causal inferences.

Nonetheless, the descriptive empirical work can help understand how the HAGC bidding process worked and how firms responded to the HAGC program in equilibrium. Moreover, it reveals interesting and important patterns that may suggest causal effects and guide our structural analysis of the firms' post-bidding pricing stage (in Chapter 3). People might investigate these patterns further using other (maybe structural) methods in future research, especially if the information on losing bids becomes available.

The remainder of this chapter proceeds as follows. Section 2.1 reviews additional related literature about subsidy policy designs with bidding and cell phone or smartphone mar-

kets. Section 2.2 and 2.3 provide additional background information on the firms' bidding in the HAGC subsidy program, and the Chinese cell phone market. Section 2.4 describes the data used in this chapter (and Chapter 3). We analyze the characteristics of winners of the HAGC bidding in Section 2.5 and the relation between the HAGC subsidy program and various market outcomes in Section 2.6.

2.1 Literature

A critical component of the HAGC program was the firms' bidding for subsidy eligibility, as described in detail in Section 2.2. The HAGC-style bidding design was used by other subsidy programs in China, such as a subsidy for energy-saving home appliances in 2012-2013 and another for automobiles in 2021. Given the size and the influence of the HAGC program on both consumers and firms after the 2008 economic crisis and the repeated trials of such bidding designs in China, the economic analysis of firms' bidding for subsidy eligibility is worthy of attention.

Some studies investigate the firms' bidding for subsidy eligibility in other subsidy programs, including the infant formula rebate of the "Women, Infants, and Children" (henceforth, WIC) program by the United States Department of Agriculture (henceforth, USDA).[3] David Davis, with the support from USDA and the Center on Budget and Policy Priorities, keeps track of the bids and contracts of WIC's infant formula rebate program (Oliveira and Davis 2015) and studies the effect of state agency alliances on lowering bids (Davis 2014) and the effect of the infant formula rebate on the wholesale prices and non-WIC customers (Davis 2012). Oliveira et al. (2010) and Oliveira et al. (2011) also document and analyze the changes in wholesale and retail prices as well as market shares

[3]WIC assists low-income families and their children in purchasing healthy foods. In the infant formula rebate program by WIC, eligible households receive infant formula vouchers from state WIC agencies. The vouchers apply to a single infant formula brand in each state, determined by a bidding process. Specifically, the manufacturer that offers the WIC state agency the lowest predicted net price, as determined by the manufacturer's wholesale price in the previous year minus the rebate, wins the exclusive contract.

in the US infant formula market.

However, our study of the HAGC program is different in three ways from the studies mentioned above. First, the bidding for WIC's infant formula rebate does not impose any price control despite that the manufacturer's wholesale price in the previous year is taken into consideration when the bid is evaluated. In contrast, the HAGC program imposed price ceilings on the subsidized products, and in Chapter 3, we highlight the role of price ceilings in tackling what hinders the consumer gains from the subsidy – the price increase arising from the subsidy. Second, almost only three giant manufacturers in the US infant formula industry repeatedly take part in the bidding for WIC's rebate. In contrast, the market structure of the Chinese cell phone market under the HAGC program was much more competitive with a large number of competitors, which might result in very different policy implications. Third, most of these studies are descriptive analysis, while this dissertation includes structural modeling and estimation of demand and pricing that allow us to analyze the welfare effect of the subsidy program by counterfactual simulations (in Chapter 3).

A few previous studies on cell phone or smartphone markets from various aspects are also worth noting, and we complement these papers by studying a consumer subsidy with firms' bidding for subsidy eligibility in this industry. The most relevant to this dissertation is Wang (2018), which uses the cell phone sales data from the same source as this dissertation. He looks into the Chinese smartphone market, uses a data set covering a relatively later period till 2014, focuses on firms' innovation and product portfolio choices, and finds that one Chinese pro-competitive industrial policy crowded out the incumbent firms' new-product incentives and the incumbents also strategically downgraded product lines to compete with the low-end entry. In the context of the US market, Fan and Yang (2020) study how oligopolistic competition impacts firms' endogenous product portfolio choices and welfare implications and find that a reduction in competition decreases product number and product variety and reduces total welfare.

Zhu et al. (2015) study the welfare effect of exclusive handset contracts between APPLE's iPhone and AT&T and find the exclusive dealing arrangements harmful to consumer welfare. Sinkinson (2020) points out that AT&T had the highest willingness to pay for exclusivity with APPLE only after accounting for equilibrium price effects and that this exclusivity increased entry incentives for rivals.

2.2 Product Eligibility and Incentives to Curb Prices

Section 2.2 is an essential component of the joint work in Chapter 3 with Ying Fan.

In the HAGC subsidy program, firms must compete in a bidding to make their products eligible for the subsidy. Each participating firm proposed a list of products and a corresponding price ceiling for each product, together with a list of provinces. If a product was eventually chosen to be eligible for the HAGC subsidy in a province and month, the price ceiling became a constraint to the product's firm when choosing its retail price in the province and month. The list of provinces must be the same for all the listed products, and the price ceiling for a listed product must be the same for all the listed provinces. The left panel of Figure 2.1 presents a hypothetical example of a firm's proposal.

A committee from China's Ministry of Finance and Ministry of Commerce evaluated these proposals based on product characteristics, firm characteristics (e.g., previous sales, customer services in each province), and, most importantly, the price ceiling. Although the evaluation criteria might be opaque, it was common knowledge that submitting a lower price ceiling, *ceteris paribus*, would increase the chance of a product being chosen for the program. Such competition for subsidy eligibility curbed firms' incentives to raise prices under the subsidy.

Multiple products from multiple firms could be eligible for the subsidy simultaneously. The evaluation committee might decline some of the products and some of the provinces on a proposal while accepting the other products and provinces as winners, but they

would never impose a price ceiling different from that on the proposal. The right panel of Figure 2.1 presents a hypothetical example of the same firm's winning proposal.

Unobserved Original Proposal

Firm	Product	Ceiling	Province
BIRD	Bird S368	299	Anhui, Gansu, Hunan
	Bird T800	899	
	Bird D719	599	

Observed Winning Proposal

Firm	Product	Ceiling	Province
BIRD	Bird S368	299	Anhui, Gansu
	Bird T800	899	

Figure 2.1: A Hypothetical Example of Proposal

The winning proposals (i.e., the right panel of Figure 2.1) were publicly announced and observable to us. Unfortunately, we do not observe the original proposals that firms submitted (i.e., the left panel of Figure 2.1) as it is confidential information protected by the government. In other words, we do not observe the suppliers that participated in the bidding but had no winning product; for a supplier that had at least one winning product, we do not observe whether this supplier had bid for other products, and if so, what the proposed price ceilings were.

There are some details about the pricing restrictions that are worth noting. First, a product was not subject to a price ceiling if it was not subsidized in the province and month, e.g., the product lost or did not participate in the bidding, or the subsidy was not available in the province, or the subsidy had ended. Second, although a subsidized product was subject to the same price ceiling across provinces and months, the firm could still set different retail prices across provinces and months. Third, some consumers were eligible for the subsidy while others are not (Section 1.4), but the retail price (and the price ceiling if applicable) was the same to all consumers in the same province and month. Fourth, proposed price ceilings in the cell phone category must be below 1,000 CNY in 2008-2009 and below 2,000 CNY in 2010-2012. Despite the higher allowed limit of 2,000 CNY in 2010-2012, the majority of products chosen for the HAGC program still had price ceilings below 1,000 CNY. The maximum rebate amount for the cell phone category remained at 130 CNY, the 13% rebate rate times the initial 1,000 CNY limit.

2.3 The Chinese Cell Phone Industry

There are some other characteristics of the Chinese cell phone market that are relevant to this dissertation. First, the term "price" in the dissertation and our sales data refers to the price for a cell phone handset, excluding any promotion or service charge by mobile carriers. While cell phones in the US were typically sold together with wireless service plans as a bundle before T-Mobile's "un-carrier" campaign in 2013, the majority of cell phone handsets in China, including the sales via carriers' channels, were sold separately from a wireless network service contract during the time of the data. Unlike the studies on the US cell phone market reviewed in the literature section, our study does not need to model the double marginalization between cell phone producers and wireless carriers. We can make the reasonable simplifying assumption that the cell phone firms choose the final retail prices to the end consumers in our model.

Second, the dominating in-store sales of cell phone handsets were run by provincial segments during the HAGC program, so was the product eligibility for the HAGC subsidy. The online sales only accounted for 8.75% of the total sales units during the HAGC program, and the data source reports online sales only at the national level without providing a breakdown at the province level. Hence we treat each province as a separate market, assume that all the products observed in the market are in the choice set of all consumers in that market, and drop online sales from our further analysis.

Third, almost all the cell phone handsets sold in the Chinese market during or around the HAGC subsidy program were produced domestically, either by a domestic firm (e.g., HUAWEI) or by a joint-venture enterprise with a foreign brand or a domestic producer with brand licensing (e.g., NOKIA). Hence, when we analyze the HAGC program's welfare effects and policy implications, it is proper to ignore the import of cell phone handsets from foreign countries.

Fourth, there were a wide variety of cell phones produced by small domestic firms, espe-

cially at the low end of the Chinese market. This fact made the Chinese cell phone market relatively more competitive compared to many other oligopoly markets and might play an essential role in shaping the welfare implication of the subsidy in this market. These small firms were more likely to enter the provincial markets with larger and wealthier populations, generating variations in consumers' product choice sets across provinces.

Fifth, all the major acquisitions and mergers in the Chinese cell phone handset market were irrelevant to the market structure in our analysis of the HAGC program,[4] while a single firm might advertise its products as different brands and might have subsidiaries operating with different brands. For example, TCL kept ALCATEL as a different brand after acquiring its cell phone handset business in 2005. We model such a case as a single firm choosing prices for all its products regardless of the associated brands to maximize the total profit from all its brands.

2.4 Data

Section 2.4 is an essential component of the joint work in Chapter 3 with Ying Fan.

Unless otherwise specified, a "market" throughout the dissertation refers to a province/time combination, and an "observation" refers to a market/product (i.e., province/time/product) combination. "Eligible firm" refers to a firm with at least one eligible product in the province and time, while "eligible product" and "subsidized product" refer to an observation where the product is eligible for the subsidy in the province and time.

Our cell phone sales data come from GfK, a leading market research company for consumer products.[5] The data set includes the universe of cell phones sold in mainland China between July 2007 and June 2013, from six months before the HAGC program to

[4]See Appendix A for more details.

[5]https://www.gfk.com/en-us/home

six months after it. We observe the total number of units sold and the average price for each cell phone product in every month in the sample and every province in mainland China.[6]

Key characteristics of each product are also available in the data set. Specifically, we observe whether a product is a smartphone or a feature phone, whether it includes a camera, whether it includes a touch screen, whether it supports the 3G network, whether it supports dual SIM, whether it has a "flip" or "slider" design, storage in gigabytes, camera resolution in megapixels, and handset size in inches.[7] On the rare occasions of missing characteristics data, we hand-collect the information from *The List of Telecommunications Equipment Approved for Network Access Licenses (Including Trial Approvals)* (in Chinese) by China's Ministry of Industry and Information Technology (henceforth, the MIIT list)[8] and GSMArena.com.

Data on the winning proposals come from the China National Electronics Import and Export Corporation, the HAGC subsidy program's bidding agency.[9] We observe the eligible products, their price ceilings, the eligible provinces, and the eligible dates for each bidding round. We then link the HAGC subsidy data to the Chinese cell phone sales data by matching the product model name (and the eligible markets). In some cases, the model name of a product listed in the HAGC winning proposals may not exactly match the same product's model name in the GfK cell phone sales data. We manually check each matching (or not) by comparing all the related model names and product characteristics from the HAGC documents, the GfK sales data, the MIIT list, and GSMArena.com. The rare remaining ambiguous cases have tiny sales and are dropped.

[6]We drop the sales in Tibet because Tibet has a tiny population and cell phone sales, leading to imprecise measures of the average prices and market shares.

[7]Appendix B introduces the exact definitions of cell phone characteristics.

[8]http://www.miit.gov.cn/newweb/n1146285/n1146352/n3054355/n3057709/n3057720/index.html

[9]https://www.ceiec.com

We aggregate the data from the monthly level to the quarterly level, i.e., sum up the sales units and revenues in the months within a quarter.[10] We do so because quarterly sales are measured more precisely than monthly ones. We drop an observation if its number of sales units is no larger than 500 because such a number and the corresponding average price are not likely to be precisely measured or have non-negligible impacts on market outcomes.

Figure 2.2 plots the histograms of the price ceilings and the ratios of retail prices to price ceilings. The upper panel shows the distribution of price ceilings in CNY. The median, indicated by the vertical line, is 658 CNY. The distribution is skewed to the left, consistent with the HAGC program's focus on low-end products. There is bunching at or just below 1,000 CNY because firms could not propose a price ceiling above 1,000 CNY in 2008 and 2009. The lower panel shows the distribution of the ratios of retail prices to price ceilings, with a median of 82%. The observations on the right end of the panel are those with binding pricing constraints or with prices close to their price ceilings.

[10]The three months in a quarter may not belong to the same round of HAGC subsidy. In such cases, we aggregate the two months belonging to the same round into one observation and keep the other single month as a separate observation. We make corresponding adjustments when calculating market shares. For simplicity, we still use "quarter" to refer to such observations.

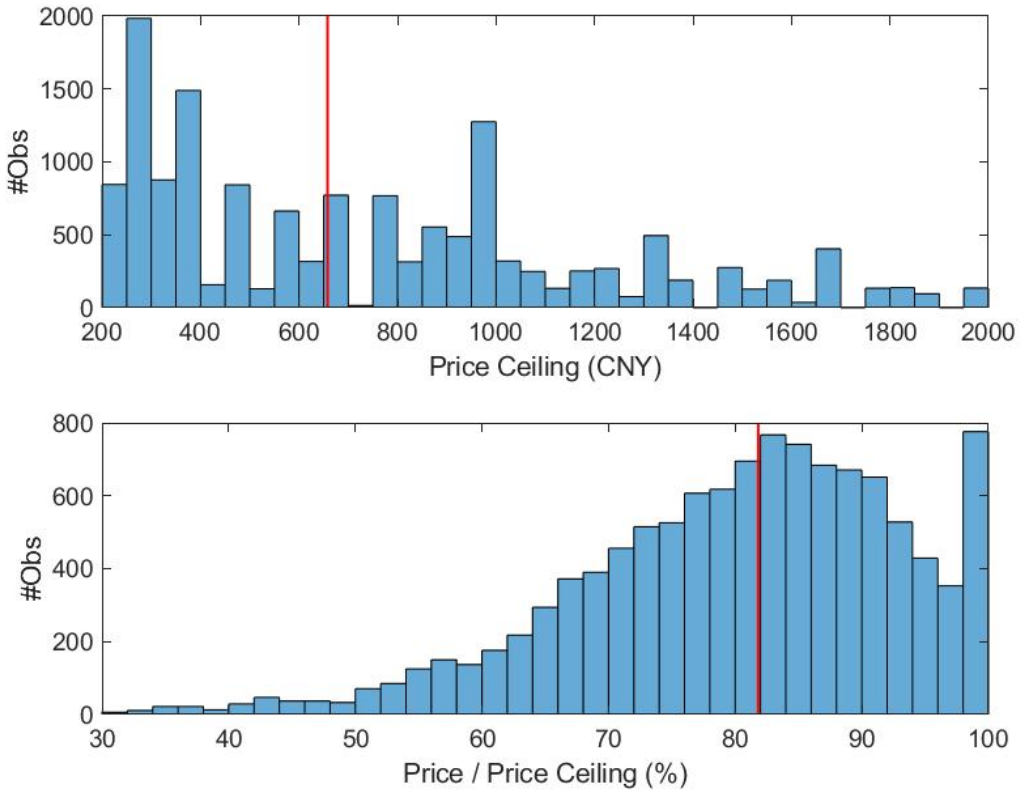


Figure 2.2: Histograms of Price Ceilings

2.5 Winners and Binding Price Ceilings

2.5.1 Which Firms Won?

We first look at which firms had been eligible for the HAGC subsidy programs and their sales. There are two commonly used measures of sales, the number of handset units sold (henceforth "units") and the total value in CNY of handsets sold (henceforth "revenue").

The term "sales share" throughout this dissertation refers to the percent of total sales in the market generated by a particular firm. This metric is widely named as market share in business practice, but the term "market share" throughout this dissertation, following the literature in modern empirical industrial organization, refers to the choice probability in the discrete choice specification or the number of sales units divided by the population

of consumers in the market.

We calculate the sales shares of each firm in Table 2.1, measured by sales units in Columns (2) and (4) and by sales revenue in Columns (3) and (5). Columns (4) and (5) count the sales of all products during the HAGC subsidy program, and Columns (2) and (3) only count those of eligible products.[11] The firms are first sorted by Column (2) and then by Column (4). Column (1) shows whether the firm's brand is owned by an entity in mainland China.

Table 2.1 shows that the HAGC subsidy program covered the major firms (in the relatively low-end space of the Chinese cell phone market) while 14 smaller Chinese firms grouped into "other eligible" had also been eligible for the HAGC subsidy program. The HAGC-eligible firms account for 84% of the total sales units, with NOKIA and SAMSUNG as the leading two for 53%. The sales shares of all or eligible products measured by units or revenue are typically in line with each other, except for NOKIA's large share of eligible products and MOTOROLA's small one. NOKIA's large share is consistent with the government's announced preferences for firms that "best meet rural consumers' needs" by their highly durable products and large numbers of customer service centers.

Some large firms were excluded from the HAGC program for various reasons. According to media reports, SONY and COOLPAD opted out from the HAGC program due to their concerns about brand image harms since the program focused on low-end products. All the APPLE products were priced above the upper price limit of the HAGC program, and similarly for OPPO who focused on smartphones. HTC from Taiwan was also excluded.

[11] Columns (2) and (3) include HAGC-eligible products purchased by any consumer and thus are not all subsidized by the HAGC program. The sales numbers to HAGC-eligible consumers are not observable in our data.

Table 2.1: Sales Shares and Subsidy Eligibility

Firm	(1) Mainland Chinese Brand?	(2) Shares within Eligible Products: Units	(3) Shares within Eligible Products: Revenue	(4) Shares among All Products: Units	(5) Shares among All Products: Revenue
NOKIA		47.81%	49.87%	29.53%	25.38%
SAMSUNG		24.83%	23.77%	23.94%	27.04%
HUAWEI	Yes	5.11%	3.79%	5.61%	3.46%
K-TOUCH	Yes	4.92%	6.29%	2.30%	1.36%
ZTE	Yes	4.34%	2.94%	5.03%	2.84%
LENOVO	Yes	3.25%	4.12%	5.00%	3.49%
HISENSE	Yes	2.47%	1.92%	0.89%	0.47%
HAIER	Yes	1.73%	1.39%	0.48%	0.19%
CHANGHONG	Yes	1.14%	1.49%	0.37%	0.22%
GIONEE	Yes	1.13%	1.42%	2.44%	2.17%
LG		1.06%	0.63%	2.01%	1.49%
BIRD	Yes	0.71%	0.58%	0.35%	0.17%
MOTOROLA		0.44%	0.45%	3.12%	4.16%
Other eligible	Yes	1.07%	1.34%	2.52%	2.24%
COOLPAD	Yes			3.31%	2.78%
OPPO	Yes			2.77%	3.56%
APPLE				2.44%	10.29%
SONY				1.49%	2.25%
HTC				1.19%	2.61%
Other ineligible	Yes/No			5.21%	3.82%

The eligible firms are sorted by the sales unit share within eligible products, and the ineligible firms by the sales unit share among all products.

2.5.2 Which Products Won?

As only about 10% of the cell phone models below the upper price limit were eligible for the HAGC subsidy program, it is interesting to see which specific products of the winning firms were eligible. Tables 2.2 and 2.3 present the logistic regressions of the dummy for being a winning product on cell phone characteristics, firm dummies, a few other variables of interest, and yearly dummies.[12] Keep in mind that the observed eligible products are the ones that firms chose to submit and the government decided to subsidize, so these results are about the correlations of the equilibrium outcomes.

The observations are at the product/year level since the eligibility was determined yearly. The observations before or after the HAGC program, the products of ineligible firms, and the products priced above the upper price limit are excluded from these regressions because they were impossible to be eligible. We analyze the sub-sample of 2008-2009 (Table 2.2) and that of 2010-2012 (Table 2.3) separately because of the different upper price limits.

The regressions for both sub-samples show that products with lower prices[13] and larger numbers of sales units in the previous year and "younger" products[14] are more likely to be eligible for the HAGC subsidy program, and the above associations are statistically significant except for the price in 2008-2009. These findings are consistent with the government's announced preferences for less expensive products with "proved popularity" (as measured by past sales). There were suspects that firms might strategically submit outdated models to the HAGC program in order to clear the inventories. Our results do not disprove such suspicion since we observe equilibrium outcomes rather than all firms'

[12]Since only eligible products have (observed) price ceilings, we do not include the price ceiling variable in these regressions but leave it for Section 2.5.3.

[13]All the price or ceiling variables in the tables of Section 2.5 are in 1,000 CNY unless otherwise specified.

[14]A product's "age" is defined as the number of months since its release date.

submissions, but they show that the eligible products are not older than average.

As expected, the eligibility is positively associated with many favorable cell phone characteristics and sometimes significantly so, and none of its negative correlations with characteristics is significant. All the significant firm fixed effects are the positive ones in 2010-2012 for mainland Chinese brands, consistent with the government's aim to support local brands to survive and develop after the financial crisis.[15]

2.5.3 Which Price Ceilings Won?

As the proposed price ceilings are only observed for winning products and can not be included in the analysis in Section 2.5.2, we use the sample of eligible products to run regressions of price ceilings on cell phone characteristics, firm dummies, a few other variables of interest, and yearly dummies. The observations are at the product/year level.

Columns (1) and (2) in Table 2.4 present the results of ordinary least squares, and for comparison, Columns (3) and (4) for the Tobit model using the sub-sample of 2008-2009, and Columns (5) and (6) for Tobit estimates of 2010-2012. We run Tobit analyses because price ceilings are censored (at the upper price limit) continuous outcomes, and the Tobit estimates can be more reliable than OLS in this case if the error term is normally distributed. Similarly to Section 2.5.2, we run separate Tobit estimations for 2008-2009 and 2010-2012 due to different upper price limits and have several variables omitted from the regressions.

As expected and in all the three regressions, the price ceilings are significantly positively

[15]The variables of smartphone dummy and storage memory are omitted in Table 2.2 because smartphones were very rarely below 1,000 CNY by the year 2009, and the variation in storage memory mainly came from smartphones. The dummy for MOTOROLA is omitted in Table 2.3 because very few products by MOTOROLA during that time were below 2,000 CNY.

Table 2.2: Logistic Regressions of Being a Winning Product in 2008-2009

Variable	(1) Est.	(2) S.E.	(3) Est.	(4) S.E.
Panel I: Cell Phone Characteristics				
Smartphone (v.s. feature phone)	(Omitted)		(Omitted)	
Include camera	0.64	(0.52)	0.87	(0.55)
Include touch screen	0.29	(0.41)	0.18	(0.43)
Support 3G network	1.55	(0.81)	1.34	(0.89)
Dual SIM card	-0.15	(0.50)	-0.37	(0.51)
Design: flip	0.79	(0.75)	0.04	(0.80)
Design: slider	0.43	(0.70)	-0.58	(0.77)
Storage memory (normalized)	(Omitted)		(Omitted)	
Camera resolution (normalized)	-0.41	(2.59)	1.39	(2.79)
Handset size (normalized)	12.60	(8.34)	-1.92	(8.84)
Panel II: Firm Fixed Effects				
NOKIA	-0.50	(0.65)	-1.18	(0.75)
SAMSUNG	0.29	(0.68)	-0.76	(0.77)
HUAWEI	0.21	(0.95)	-0.07	(1.03)
K-TOUCH	-0.21	(0.54)	-0.50	(0.56)
ZTE	0.28	(0.74)	0.46	(0.76)
LENOVO	-0.46	(0.63)	-1.00	(0.68)
HISENSE	1.19	(1.26)	1.98	(1.70)
HAIER	0.77	(0.69)	-0.36	(0.74)
CHANGHONG	0.23	(0.61)	0.42	(0.62)
GIONEE	-0.61	(0.84)	-1.46	(0.91)
LG	0.06	(0.83)	-0.59	(0.90)
BIRD	0.04	(0.63)	-0.28	(0.67)
MOTOROLA	-1.43	(0.73)	-1.35	(0.75)
Panel III: Others				
Constant	-11.33*	(3.73)	-6.55	(3.89)
Lagged price	-1.89	(1.13)	-0.54	(1.19)
Log of lagged sales units	0.23*	(0.09)	0.53*	(0.12)
Age of the product in months			-0.12*	(0.02)
Year dummies	Yes		Yes	
Number of Observations	701		701	

* p<0.01. Reported are the coefficients of logits (log odds). The firm dummies are listed in the order of the sales unit share within eligible products, and the control group is all the other (smaller) eligible firms.

Table 2.3: Logistic Regressions of Being a Winning Product in 2010-2012

Variable	(1) Est.	(2) S.E.	(3) Est.	(4) S.E.
Panel I: Cell Phone Characteristics				
Smartphone (v.s. feature phone)	0.24	-0.61	-0.11	-0.62
Include camera	0.50	(0.24)	0.71*	(0.25)
Include touch screen	0.43	(0.18)	0.49*	(0.18)
Support 3G network	1.19*	(0.20)	0.68*	(0.21)
Dual SIM card	0.17	(0.19)	0.03	(0.20)
Design: flip	0.51	(0.29)	0.32	(0.31)
Design: slider	0.11	(0.23)	-0.04	(0.24)
Storage memory (normalized)	0.34	(2.68)	-1.23	(2.83)
Camera resolution (normalized)	-2.27	(1.05)	-1.60	(1.11)
Handset size (normalized)	7.94*	(2.61)	4.21	(2.67)
Panel II: Firm Fixed Effects				
NOKIA	0.57	(0.32)	0.71	(0.35)
SAMSUNG	-0.02	(0.33)	-0.23	(0.35)
HUAWEI	0.01	(0.40)	-0.19	(0.41)
K-TOUCH	1.02*	(0.27)	0.99*	(0.28)
ZTE	0.43	(0.35)	0.19	(0.36)
LENOVO	0.63	(0.31)	0.50	(0.32)
HISENSE	2.92*	(0.39)	2.86*	(0.41)
HAIER	4.26*	(0.41)	4.34*	(0.42)
CHANGHONG	1.12*	(0.34)	2.23*	(0.38)
GIONEE	-0.64	(0.38)	-0.62	(0.39)
LG	-0.06	(0.41)	-0.38	(0.42)
BIRD	1.33*	(0.37)	1.61*	(0.38)
MOTOROLA	(Omitted)		(Omitted)	
Panel III: Others				
Constant	-6.88*	(1.30)	-4.47*	(1.34)
Lagged price	-1.26*	(0.30)	-1.46*	(0.32)
Log of lagged sales units	0.24*	(0.04)	0.33*	(0.05)
Age of the product in months			-0.09*	(0.01)
Year dummies	Yes		Yes	
Number of Observations	2,630		2,630	

* p<0.01. Reported are the coefficients of logits (log odds). The firm dummies are listed in the order of the sales unit share within eligible products, and the control group is all the other (smaller) eligible firms.

associated with the price in the previous year, positively with most cell phone characteristics, and significantly so with many. The partial correlations with sales units in the previous year and firm dummies are mostly not significant, suggesting that the government's preference for popular products and major local brands might be limited to the winning probability but not price ceilings. Keep in mind that all these results are for equilibrium outcomes rather than firms' strategies or the governments' evaluation function.

2.5.4 Which Price Ceilings Were Binding?

The most interesting feature of the HAGC subsidy program is the bidding process imposing price ceilings on the eligible products. Observations with binding price ceilings are exactly why such policy design may mitigate the price increase under the subsidy and improve consumer welfare. Before we move on to the structural estimation of the welfare effect of the price ceilings in Chapter 3, we look into which observations are subject to binding price ceilings.

Table 2.5 presents the logistic regression of the dummy for having a binding price ceiling on cell phone characteristics, firm dummies, a few other variables of interest, and province and year dummies. The sample consists of the product/market-level observations that are eligible for the subsidy in the corresponding market.

As expected, having a binding price ceiling is significantly associated with price and ceiling measures: negatively with the price ceiling and positively with the price in the previous year in Column (1), and negatively with the ratio of current price ceiling over price in the previous year in Column (3). There is no evidence for the effect of having a ceiling at the upper price limit on having a binding ceiling. The results also indicate that the products of large firms are less likely to have binding price ceilings than those of small firms, and significantly so for many large firms.

Table 2.4: Regressions of Winning Price Ceilings

	(1)	(2)	(3)	(4)	(5)	(6)
Method	OLS		Tobit		Tobit	
Sample Year	2008-2012		2008-2009		2010-2012	
Variable	Est.	S.E.	Est.	S.E.	Est.	S.E.
Panel I: Cell Phone Characteristics						
Smartphone	0.15	(0.11)	(Omitted)		0.17	(0.11)
Include camera	0.23*	(0.03)	0.15*	(0.05)	0.24*	(0.03)
Include touch screen	0.09*	(0.02)	-0.04	(0.04)	0.10*	(0.02)
Support 3G network	0.19*	(0.03)	0.00	(0.06)	0.18*	(0.03)
Dual SIM card	-0.05	(0.02)	0.07	(0.04)	-0.05	(0.03)
Design: flip	0.18*	(0.04)	0.24*	(0.07)	0.17*	(0.04)
Design: slider	0.22*	(0.03)	0.30*	(0.07)	0.21*	(0.03)
Storage memory	-0.37	(0.51)	(Omitted)		-0.27	(0.54)
Camera resolution	0.64*	(0.12)	0.31	(0.21)	0.67*	(0.14)
Handset size	2.20*	(0.39)	3.79*	(0.80)	2.27*	(0.44)
Panel II: Firm Fixed Effects						
NOKIA	-0.08	(0.04)	0.01	(0.06)	-0.11	(0.05)
SAMSUNG	-0.10	(0.04)	-0.01	(0.06)	-0.14*	(0.05)
HUAWEI	-0.12	(0.05)	-0.17*	(0.06)	-0.11	(0.06)
K-TOUCH	-0.08	(0.03)	-0.13*	(0.04)	-0.10	(0.04)
ZTE	-0.14*	(0.04)	-0.10	(0.06)	-0.17*	(0.05)
LENOVO	-0.04	(0.04)	(Omitted)		-0.06	(0.05)
HISENSE	-0.08	(0.05)	-0.01	(0.10)	-0.08	(0.05)
HAIER	0.05	(0.04)	-0.03	(0.06)	0.04	(0.05)
CHANGHONG	-0.02	(0.04)	-0.02	(0.05)	-0.05	(0.05)
GIONEE	-0.04	(0.05)	0.11	(0.08)	-0.08	(0.06)
LG	-0.09	(0.06)	-0.02	(0.07)	-0.10	(0.07)
BIRD	-0.05	(0.05)	-0.11	(0.05)	-0.05	(0.06)
MOTOROLA	-0.08	(0.10)	-0.12	(0.06)	(Omitted)	
Panel III: Other Variables						
Constant	-0.76*	(0.20)	-1.40*	(0.36)	-0.70*	(0.22)
Lagged price	0.40*	(0.03)	0.43*	(0.08)	0.42*	(0.04)
log(lag(units))	0.01	(0.01)	0.01	(0.01)	0.01	(0.01)
Year dummies	Yes		Yes		Yes	
Number of Obs.	512		92		420	

* p<0.01. The firm dummies are listed in the order of the sales unit share within eligible products, and the control group is all the other (smaller) eligible firms. Some of the variable names are abbreviated to save space, and please refer to Table 2.3 for the complete variable names.

We do not see a clear pattern (or have an unambiguous prior for) whether products with better overall characteristics, in which years, or in which provinces are more likely to have a binding price ceiling. For example, in richer provinces, a consumer may have a higher willingness to pay for cell phones, while there may be more firms and products competing in such provinces, so it is ambiguous whether prices shall be higher and price ceilings shall be more likely to be binding in richer provinces.

2.6 HAGC and the Chinese Cell Phone Industry

2.6.1 Post-HAGC Sales

Two possible "side effects" of the HAGC subsidy program on the Chinese cell phone industry had drawn public attention. On the one hand, did consumers shift their purchases to a less favorable timing in order to claim the HAGC subsidy? If so, consumers' gain from the HAGC subsidy program might be exaggerated. On the other hand, did the HAGC subsidy program, which focused on relatively low-end products, harm high-end brands' image?[16] Answering this question will guide the modeling of firms' participation in the HAGC bidding process.

To address these two questions, we regress the firm/year-level sales on the interactions between the year-level during- or post-HAGC dummies and the firm-level HAGC-eligible or -ineligible dummies, as well as some other control variables. Table 2.6 shows the results using the log units as the sales measure and Table 2.7 for the log revenue. Their Columns (1) and (3) are for all products and Column (5) for those below 2,000 CNY. Column (3) contains the interactions of during- or post-HAGC dummies and firm dummies.[17]

[16]Around 2010, Chinese consumers commonly believed that famous foreign brands stand for high quality, especially in electronics industries. SONY, MOTOROLA, and a few other firms did not participate or chose to quit the program seemingly due to such concerns about brand image.

[17]The tables only present the interactions of post-HAGC dummies and the dummies for four non-Chinese high-end brands to save space.

Table 2.5: Logistic Regression of Having Binding Price Ceiling

Variable	(1) Est.	(2) S.E.	(3) Est.	(4) S.E.
Panel I: Cell Phone Characteristics				
Smartphone (v.s. feature phone)	1.23	-1.83	-0.36	-1.52
Include camera	-0.33	(0.18)	-0.81*	(0.12)
Include touch screen	0.02	(0.13)	-0.13	(0.13)
Support 3G network	0.65*	(0.15)	0.22	(0.14)
Dual SIM card	0.53*	(0.14)	0.65*	(0.14)
Design: flip	0.29	(0.23)	0.17	(0.21)
Design: slider	0.57*	(0.20)	0.16	(0.18)
Storage memory (normalized)	18.81	(10.91)	11.40	(9.09)
Camera resolution (normalized)	-2.15	(0.86)	-4.65*	(0.62)
Handset size (normalized)	0.41	(3.10)	-1.35	(2.72)
Panel II: Firm Fixed Effects				
NOKIA	-1.02*	(0.27)	-0.83*	(0.26)
SAMSUNG	-1.11*	(0.28)	-0.99*	(0.26)
HUAWEI	-1.18*	(0.35)	-0.37	(0.34)
K-TOUCH	0.26	(0.26)	0.56	(0.25)
ZTE	-0.54	(0.32)	0.23	(0.31)
LENOVO	-0.72	(0.30)	-1.11*	(0.31)
HISENSE	-1.50*	(0.38)	-1.15*	(0.38)
HAIER	-0.88	(0.64)	-0.23	(0.66)
CHANGHONG	0.37	(0.27)	0.40	(0.26)
GIONEE	0.82*	(0.30)	0.86*	(0.28)
LG	0.52	(0.33)	0.62	(0.33)
BIRD	0.08	(0.36)	0.67	(0.35)
MOTOROLA	0.67	(0.36)	0.80	(0.35)
Panel III: Others				
Constant	-2.12	(1.44)	7.25*	(1.36)
Price ceiling	-12.40*	(0.54)		
Lagged price	10.68*	(0.46)		
Ceiling/(lagged price)			-9.75*	(0.38)
Ceiling = Max allowed	-0.68	(0.29)	0.31	(0.23)
Province and year dummies	Yes		Yes	
Number of Observations	17,566		17,566	

* p<0.01. Reported are the coefficients of logits (log odds). The firm dummies are listed in the order of the sales unit share within eligible products, and the control group is all the other (smaller) eligible firms.

The results across different sales measures, samples, and specifications have similar implications. Although the sales of HAGC-eligible firms are significantly boosted during the program as expected, there is no significant effect after the program or for ineligible firms on average. However, the sales of non-Chinese high-end brands often significantly suffered after the program except for SAMSUNG. In other words, there is no evidence that the HAGC subsidy program might crowd out the overall cell phone consumption after the program, while it could have negative post-program impacts on some specific high-end foreign brands.

Table 2.6: Differences in the Log of Sales Units

	(1)	(2)	(3)	(4)	(5)	(6)
	All products		All products		Price<2k CNY	
Variable	Est.	S.E.	Est.	S.E.	Est.	S.E.
Eligible, during HAGC	0.45**	(0.17)	0.40*	(0.16)	0.45**	(0.17)
Ineligibile, during HAGC	0.02	(0.15)	0.04	(0.15)	0.02	(0.15)
Was eligible, post-HAGC	0.00	(0.21)	0.13	(0.21)	0.00	(0.21)
Was ineligible, post-HAGC	-0.18	(0.20)	-0.21	(0.20)	-0.18	(0.20)
NOKIA post-HAGC			-1.84**	(0.25)		
SAMSUNG post-HAGC			-0.10	(0.32)		
LG post-HAGC			-1.98**	(0.27)		
MOTOROLA post-HAGC			-1.80**	(0.22)		
Other firm fixed effects	Yes		Yes		Yes	
Province&year dummies	Yes		Yes		Yes	
Number of Obs.	10,691		10,691		10,691	

** p<0.01, * p<0.05. Observations are on the firm/quarter/province level.

2.6.2 Market Entry and the HAGC Coverage

Market structure is among central topics in industrial organization research. Although a structural analysis of the HAGC subsidy program's impacts on firms' entry and product offering requires the unavailable losing bid data, it is a good starting point to check for correlations that might suggest such impacts (or not).

Table 2.7: Differences in the Log of Revenue

	(1)	(2)	(3)	(4)	(5)	(6)
	All products		All products		Price<2k CNY	
Variable	Est.	S.E.	Est.	S.E.	Est.	S.E.
Eligible, during HAGC	0.48*	(0.20)	0.44*	(0.20)	0.48*	(0.20)
Ineligibile, during HAGC	0.12	(0.18)	0.13	(0.18)	0.12	(0.18)
Was eligible, post-HAGC	0.34	(0.25)	0.42	(0.25)	0.34	(0.25)
Was ineligible, post-HAGC	-0.17	(0.24)	-0.20	(0.24)	-0.17	(0.24)
NOKIA post-HAGC			-1.81**	(0.29)		
SAMSUNG post-HAGC			0.58	(0.38)		
LG post-HAGC			-1.95**	(0.32)		
MOTOROLA post-HAGC			-1.13**	(0.27)		
Other firm fixed effects	Yes		Yes		Yes	
Province&year dummies	Yes		Yes		Yes	
Number of Obs.	10,691		10,691		10,691	

** p<0.01, * p<0.05. Observations are on the firm/quarter/province level.

Table 2.8: Numbers of Products and Firms under HAGC

	The Number of ...	Mean	Std	Corr. w/ (1)	Corr. w/ (4)
(1)	HAGC-eligible products	39	32	-	
(2)	All products	367	190	-0.11	
				(0.018)	
(3)	Products below 2k CNY	313	166	-0.14	
				(0.003)	
(4)	HAGC-eligible firms	7	4		-
(5)	All firms	35	17		-0.09
					(0.058)

The observations are the 539 province/quarter markets where at least one product was eligible for the HAGC subsidy. "Corr" stands for partial correlation coefficients controlling for the province and quarter dummies. In the parentheses are significance values.

Table 2.8 shows the partial correlation coefficients (and significance values in parentheses) between the total number of products or firms and the number of the HAGC-eligible ones, controlling for province and quarter dummies. Since the HAGC subsidy program focused on the low-end segment market under 2,000 CNY, we also calculate the correlation between the number of such low-end products and that of the HAGC-eligible ones in Row (3) of the table.

We find a significant negative partial correlation between the total number and the HAGC-eligible one, indicating that the HAGC subsidy program is associated with anti-competition changes in the number of competitors and the variety of product offerings. However, given the large number of firms and products in the Chinese cell phone industry and the small magnitudes of the correlation coefficients, such anti-competition impact of the HAGC subsidy program may not be the primary concern in this industry.

2.6.3 New Products and Technologies during HAGC

Another interesting question is about introducing new product models and upgrading to new technologies during the HAGC program. Since the HAGC bidding process required participating product models to have "sufficient" historical sales, it is natural to ask whether the subsidized models were relatively aged ones[18] and whether the subsidy program demotivated firms from developing new models. As the upgrading from 2G to 3G network and from feature phones to smartphones took place around 2010 when the HAGC subsidy program was in effect, and the products subsidized by the HAGC program were low-end and were often non-3G feature phones, one may suspect whether the HAGC program held back such technological upgrading.

Table 2.9 presents the firm/year-level regressions of weighted average product age on HAGC-related variables (and control variables). The weights are either sales unit shares or revenue shares within the firm and year, and the HAGC-related variable is either the

[18]This has been addressed in Section 2.5.2.

Table 2.9: Regressions of the Average Product Age on HAGC Variables

	Dependent Variable	HAGC Variable	Est.	S.E.	#Obs.
(1)	Average age of all products (weights: sales units)	Dummy for Being Eligible Firm	3.22*	(1.34)	1,268
(2)	Average age of all products (weights: revenue)	Dummy for Being Eligible Firm	2.92*	(1.32)	1,268
(3)	Average age of ineligible products (weights: sales units)	Average age of eligible products (weights: sales units in the last year)	0.30*	(0.15)	1,268
(4)	Average age of ineligible products (weights: revenue)	Average age of eligible products (weights: revenue in the last year)	0.30*	(0.15)	1,268

* $p<0.05$. Each row is a separate regression of the dependent variable on the HAGC variable, firm fixed effects, and year dummies. "Age" refers to the number of months since the release date of the product. The coefficients and standard errors are for the HAGC variables. Observations are on the firm/year level.

Table 2.10: Regressions of the Upgrading to 3G on HAGC Variables

	Dependent Variable	HAGC Variable	Est.	S.E.	#Obs.
(1)	Sales unit share of 3G-phones	Dummy for Being Eligible Firm	-0.05	(0.06)	1,268
(2)	Revenue share of 3G-phones	Dummy for Being Eligible Firm	-0.02	(0.06)	1,268
(3)	Growth rate of 3G-phones' sales units	Dummy for Being Eligible Firm	0.08	(0.73)	302
(4)	Growth rate of 3G-phones' revenue	Dummy for Being Eligible Firm	0.20	(0.77)	302
(5)	Log of 3G-phones' sales units	Log of eligible 3G-phones' last year sales units	0.05	(0.13)	28
(6)	Log of 3G-phones' revenue	Log of eligible 3G-phones' last year revenue	0.05	(0.16)	28

* $p<0.05$. Each row is a separate regression of the dependent variable on the HAGC variable, firm fixed effects, and year dummies. Rows (5) and (6) also include the log of 3G-phones' sales units or revenue last year. The coefficients and standard errors are for the HAGC variables. Observations are on the firm/year level.

Table 2.11: Regressions of the Upgrading to Smartphones on HAGC Variables

	Dependent Variable	HAGC Variable	Est.	S.E.	#Obs.
(1)	Sales unit share of smartphones	Dummy for Being Eligible Firm	-0.08	(0.05)	1,268
(2)	Revenue share of smartphones	Dummy for Being Eligible Firm	-0.07	(0.05)	1,268
(3)	Growth rate of smartphones' sales units	Dummy for Being Eligible Firm	0.68	(0.78)	259
(4)	Growth rate of smartphones' revenue	Dummy for Being Eligible Firm	0.91	(0.85)	259
(5)	Log of smartphones' sales units	Log of eligible smartphones' last year sales units	0.38*	(0.15)	27
(6)	Log of smartphones' revenue	Log of eligible smartphones' last year revenue	0.31	(0.15)	27

* $p<0.05$. Each row is a separate regression of the dependent variable on the HAGC variable, firm fixed effects, and year dummies. Rows (5) and (6) also include the log of 3G-phones' sales units or revenue last year. The coefficients and standard errors are for the HAGC variables. Observations are on the firm/year level.

dummy for being an eligible firm or the average eligible product age weighted by sales in the last year. In every specification, we find significant positive correlations between weighted average product age and the HAGC variable, supporting the concern that the subsidy program might discourage firms from developing new models.

Table 2.10 regresses the sales shares of 3G-enabled phones within the firm and year or the sales growth rate of 3G-enabled phones on the dummy for being an eligible firm. We also regress the log sales of 3G-enabled phones on its value in the previous year. There is no evidence for a significant effect of the HAGC program eligibility on the upgrading to 3G technology in any specification. A similar pattern is observed in Table 2.11 for the upgrading to smartphones. In a word, our results do not support the concern that the HAGC program might hold back the technological upgrading.

Chapter 3

The Welfare Effect of the HAGC Subsidy and Price Ceilings

This chapter is joint with Ying Fan (University of Michigan, Center for Economic and Policy Research, and National Bureau of Economic Research).

Intuitively, by shifting demand to the right, government consumption subsidies may lead to higher prices, and the consumer surplus gain from the subsidy may be smaller than the government subsidy payment. In reality, there may be an oligopoly market structure where each competing firm produces multiple differentiated products; the subsidy may be targeted to a subset of products and consumers, and consumers may have heterogeneous preferences. The ultimate market and welfare outcomes are determined by the interaction of the above factors and thus require empirical quantitative analysis.

The HAGC subsidy program studied in this dissertation had a built-in bidding process where firms must compete for the subsidy eligibility by submitting price ceilings for their products, which may mitigate price increases under the subsidy and improve consumer surplus. This chapter quantifies the welfare effect of the HAGC program on firms, sub-

sidized consumers, and unsubsidized consumers. Unsubsidized consumers may also be affected because the program may change retail prices, which apply to all consumers. To address the role of firms' competition for subsidy eligibility in shaping the subsidy program's welfare implications, we further decompose the overall welfare effect into those of the subsidy itself, the set of eligible products, and price ceilings.

To this end, we set up a structural model of consumer demand and firm pricing. We specify a random-coefficients discrete-choice demand model that allows consumers to differ in preferences and subsidy eligibility. We model the firms as strategically choosing prices to maximize profits subject to the constraint that they must price a subsidized product below its price ceiling. We do not model or estimate the bidding process but instead take the eligible product set and the price ceilings as given.[1] To address concerns about the selection on unobservable shocks in the bidding outcome (i.e., the eligible product set and the price ceilings), we control for the firm, region, and time fixed effects. Hence, it is reasonable to assume that the product/region/time-specific transitory shocks are unobservable to firms when they bid and the evaluation committee when deciding on the winning bids.

The existence of (binding) pricing constraints is exactly why the competition for eligibility can mitigate the price increase under subsidy and improve consumer surplus. However, such binding constraints imply that some optimality conditions are inequalities, which invalidates the usual supply estimation procedure in BLP. Instead, we develop a procedure for marginal cost estimation (and counterfactual simulation) that works with binding pricing constraints. The basic idea is first to estimate marginal cost coefficients and the empirical distribution of marginal cost shocks using the sample of the firms without eligible products, free of a sample selection bias given the timing assumption mentioned above; then repeat a "draw-and-verify" procedure to approximate the distribution of

[1]We do not observe the losing bids or participants and thus cannot estimate the bidding process. Correspondingly, in the counterfactual simulations, we focus on the counterfactual designs where the set of eligible products does not change endogenously.

marginal costs for the firms with binding pricing constraint(s). We will explain our method in detail in Section 3.4.2.

Using a sample relevant to the research questions above, we estimate the demand parameters, the marginal cost parameters, and the marginal cost distribution. Based on the estimated model, we conduct three counterfactual simulations to quantify the program's effects and highlight the role of firms' eligibility competition in mitigating price increase and improving consumer surplus.

We find that the subsidy program leads to a reduction in the prices of some products. For example, the prices of the eligible products with binding price ceilings in the data are, on average, 9.6% lower than a scenario without subsidy. The competition for eligibility does put downward pressure on prices because otherwise, we expect price increases under the subsidy. Because prices are strategic complements, even though other products' prices increase due to the subsidy program, the increases are smaller than those under the same subsidy without price ceilings.

Overall, we find that the HAGC subsidy program increases the consumer surplus and producer surplus by, respectively, 3.17 and 2.77 billion CNY, or 69% and 60% of the total government subsidy payment. However, if the price ceilings were not enforced at the pricing stage, the ratios of consumer and producer surplus gains to the total subsidy payment would become 62% and 64%, respectively, indicating that the price ceilings improve consumers' share of the subsidy. We can also use our estimates to evaluate alternative subsidy designs. For example, extending the subsidy to all products (without the competition for eligibility or price ceilings) would make these ratios 96% and 37%. Still, the predicted total subsidy payment would be six times the actual payment and might not be financially feasible. These results indicate that firms' competition for subsidy eligibility in the program benefits consumers and society while limiting the required government subsidy payments.

The remainder of this chapter proceeds as follows. Section 3.1 reviews additional (to previous chapters) related literature about subsidy or tax pass-through, and estimation methods for constrained problems. Section 3.2 describes the sample that we use for structural analysis. Section 3.3 sets up our structural model, and Section 3.4 discusses our estimation procedure and reports the estimates. In Section 3.5, we conduct counterfactual simulations for welfare analysis.

3.1 Literature

On the one hand, subsidy pass-through and tax incidence play a prominent role in the welfare analyses and policy evaluations of government subsidies and taxes, especially in the markets with imperfect competition. The pass-through rate of subsidy and tax depends on the market structure and other factors in specific settings.

To name a few, while Chetty (2009) summarizes that pass-through or incidence under perfect competition is often a "sufficient statistic" for various welfare analyses to reduce the number of structural assumptions, Weyl and Fabinger (2013) provide a theoretical discussion for the pass-through of subsidy and tax in oligopoly markets. Cabral et al. (2018) use a difference-in-differences approach and find that Medicare Advantage insurers pass through 13% of the increased government payments in the form of lower premiums in the least competitive markets but 74% in the most competitive ones. Pless and van Benthem (2019) use the pass-through of solar subsidies to solar system prices in California as a test for market power. They find that solar system buyers capture nearly the full subsidy while there is more-than-complete pass-through to lessees and conclude that solar markets are imperfectly competitive by ruling out alternative explanations. Sallee (2011) shows and proffers explanations for the puzzle that tax incentives on one hybrid car are fully captured by consumers despite the producer's binding production constraint.

This chapter is related to the broad literature on subsidy and tax pass-through as we study both the consumer surplus gain and the producer surplus gain from the subsidy.

We contribute by investigating the role of firms' bidding for subsidy eligibility as another factor that may affect the subsidy pass-through, and we show that imposing price ceilings in the subsidy program may benefit consumers while limiting government expenditure. What is more, our paper adds to the literature a case of a subsidy program to disadvantaged consumers in a developing country.

On the other hand, the firms' bidding for subsidy eligibility in the HAGC program imposed price ceilings on eligible products. We model a firm's pricing decision as a constrained optimization problem where the firm chooses prices to maximize its profit from cell phone sales but subject to the constraint that the (pre-subsidy) price of an eligible product must be less than or equal to the corresponding price ceiling. As a result, the firm's first-order conditions may include inequalities. The estimation of such a supply model is challenging because the inequalities will invalidate the structural estimation procedure suggested by Berry et al. (1995) (henceforth, BLP), which is widely used in industrial organization research but requires all the first-order conditions to be equations.

In some supply models from the trade and environmental economics literature, firms also face certain constraints. One way to solve or circumvent this challenge is to include the Lagrange multipliers in the optimality conditions as additional (often nuisance) parameters, which often requires (maybe strong) assumptions of grouping Lagrange multipliers so that they can be identified and estimated. For example, Goldberg (1995) studies the US automobile industry where the Japanese firms faced export quota constraints and has to assume that the Lagrange multipliers (i.e., the shadow prices of quotas) are the same across different firms within a year.

However, in our case, a firm faces one separate pricing constraint for each subsidy-eligible product in each province and time, leaving no variation to identify the hundreds of Lagrange multipliers. Even if we make a strong assumption that all the Lagrange multipliers

(i.e., the shadow prices of price ceilings) are the same across products by the same firm, months within a year, and all relevant provinces, we will still end up with 31 different Lagrange multipliers, which are too many to be estimated precisely in practice.

A possible alternative way to deal with the inequalities among optimality conditions may be the moment inequalities approach, which is increasingly used by applied work in industrial organization. In Manski (2003) and a series of other papers, Manski argued in favor of incomplete models where the constraints are often expressed as inequalities. Ciliberto and Tamer (2009) apply the approach to the multiple equilibria of market entry and suggest using sufficient-but-not-necessary conditions to construct moment inequalities. Pakes et al. (2015) propose a moment inequalities framework free of fully parametric assumptions, and Chesher and Rosen (2017) provide another that generalizes incomplete instrumental variable models. See, among others, Chernozhukov et al. (2007) and Andrews and Shi (2013) for the related econometrics about partial identification and inference.

Despite the methodological work and recent empirical applications in industrial organization, the moment inequalities approach does not seem a suitable solution to our case. The moment inequalities approach has an advantage when the necessary and sufficient conditions are hard to write down for computing likelihood, which is not the problem we are facing. Our optimality conditions cannot be equivalently transformed into a system of inequalities on one structural error each. If we apply the moment inequalities approach, we have to use much weaker conditions (than the initial optimality conditions) to construct moments, losing much identification power and resulting in very imprecise estimation. Instead, we develop a supply estimation procedure in Section 3.4.2 that extends the classic BLP framework to handle the price ceiling constraints.

3.2 Data

We construct our sample for the analysis in this chapter as follows based on our data described in Section 2.4. In addition to dropping observations from Tibet and online sales in Section 2.4, we drop observations from Beijing and Shanghai. Beijing and Shanghai have a small share of consumers eligible to claim the HAGC subsidy and thus are not very relevant to our analysis of the subsidy program. Moreover, consumers in such super metropolises may have different preferences on cell phones.

We then drop an observation (a product/province/quarter combination) if the product accounts for less than 0.1% of the total sales units in that province and quarter. We also drop a product if its price is always above 2,000 CNY in the sample. The HAGC-eligible products are mostly low-end products priced below 1,000 CNY. Thus, the high-end products and their targeted consumers have little influence on the welfare analysis of the subsidy program on low-end products. Finally, we drop an observation if the product is released or discontinued in the quarter because the sales in such cases are highly subject to (unobserved) product inventory and do not necessarily reflect the underlying consumer preferences. All these dropped products are part of the outside option.

The final sample consists of 98,446 observations (product/province/quarter combinations) from 728 markets (province/quarter combinations of 28 provinces in 26 quarters). There are 3,457 distinct products and 205 distinct firms, among which 390 products and 20 firms are ever eligible for the HAGC subsidy.

Table 3.1 presents the summary statistics of sales units, price, and key characteristics at the observation level. The first four columns report summary statistics for the full sample, the fifth for subsidized observations, and the last for observations with binding pricing constraints (i.e., the retail price equals the price ceiling). From the table, we can see that the mean retail price and characteristics of the subsidized products are lower than those of the full sample, indicating that the HAGC program focused on low-end

products. 11% of the observations are subsidized, and 4% of subsidized observations have binding pricing constraints. These 453 observations with binding pricing constraints show the effectiveness of firms' competition for subsidy eligibility in mitigating price increase under subsidy and improving consumer surplus. Since prices are strategic complements, they also put downward pressure on other non-binding or unsubsidized products.

3.3 Model

3.3.1 Demand Model

We specify a random-coefficients discrete-choice demand model. There are four types of consumers determined by their Hukou type ($h = A$ for agriculture Hukou, and $h = NA$ for non-agriculture Hukou) and their residence location ($l = R$ for being in a rural area, and $l = U$ for being in an urban area). Consumers with different Hukou types face different effective prices for products eligible for the HAGC subsidy. We allow consumers with different residence locations to have different preferences on prices and cell phone characteristics. Preference is more likely to differ across residence locations than Hukou types because factors that affect cell phone demand, such as how they use cell phones in daily life, are more related to where they currently live and work than their household registration type in the government's system.

Specifically, the utility that consumer i with Hukou h and residence l in province m and quarter t gets from purchasing product j (produced by firm $f(j)$) is

$$\begin{aligned} u_{ijmt}^{h,l} = \rho^l + \beta X_j + \tilde{\alpha}_{imt}^l (p_{jmt} - b_{jmt}^h(p_{jmt})) \\ + Firm_{f(j)} + Time_t + Province_m + \xi_{jmt} + \varepsilon_{ijmt}. \end{aligned} \tag{3.1}$$

where X_j is a vector of observable product characteristics, p_{jmt} is the retail price, and

Table 3.1: Summary Statistics of Cell Phone Sales and Characteristics

	Overall				Subsidized	Binding
Variable	Mean	Std	Min	Max	Mean	Mean
Number of units sold	6,536	13,935	500	893,457	8,299	5,454
Retail price (1,000 CNY)	1.00	0.63	0.11	3.00	0.59	0.61
Smartphone (v.s. feature phone)	0.25				0.08	0.01
Include camera	0.77				0.60	0.55
Include touch screen	0.32				0.20	0.21
Support 3G network	0.30				0.17	0.18
Dual SIM card	0.13				0.07	0.25
Design: flip	0.10				0.07	0.10
Design: slider	0.17				0.15	0.10
Storage memory (GB)	1.08	1.10	0.01	16.00	0.94	0.99
Camera resolution (MP)	2.00	1.52	0.10	12.00	1.24	1.12
Handset size (inch)	4.67	0.37	2.88	8.74	4.56	4.61
Number of Observations		98,446			11,309	453

$b^h_{jmt}(p_{jmt})$ is the subsidy amount. $b^h_{jmt}(p_{jmt})$ depends on whether j is eligible for subsidy in market mt, whether the consumer is eligible for subsidy, and the retail price of the product as follows. Let $\mathcal{J}_{mt}$ and $\mathcal{J}^e_{mt}$ represent, respectively, the set of all products and the set of products eligible for subsidy in market mt. For consumers with non-agricultural Hukou ($h = NA$) or for products that are not eligible for the subsidy ($j \in \mathcal{J}_{mt} \setminus \mathcal{J}^e_{mt}$), $b^h_{jmt} = 0$. For consumers with agricultural Hukou ($h = A$) and eligible products ($j \in \mathcal{J}^e_{mt}$), the amount of subsidy is 13% of the retail price up to a maximum subsidy of 130 CNY. In sum, $b^h_{jmt}(p_{jmt}) = \mathbb{1}\{h{=}A\} \cdot \mathbb{1}\{j{\in}\mathcal{J}^e_{mt}\} \cdot min\{p_{jmt}, 1000\} \cdot 13\%$.

The random coefficient $\tilde{\alpha}^l_{imt}$ captures consumers' heterogeneous price sensitivity and is assumed to follow a normal distribution depending on consumer i's residence location, i.e., $\tilde{\alpha}^l_{imt} = \alpha^l + \sigma_\alpha \nu_i$, where $\nu_i \overset{iid}{\sim} N(0,1)$. We also allow consumers' general taste for cell phones, ρ^l, to differ by consumers' residence location.

We allow for *demand-side* fixed effects $Firm_{f(j)}$, $Time_t$, and $Province_m$ in the utility function (3.1) to capture systematic differences across firms, quarters, and provinces. We also include the term ξ_{jmt} to capture unobservable demand shock at the product/province/quarter level.

Finally, the term ε_{ijmt} captures consumer i's idiosyncratic taste and is assumed to be i.i.d. across individual consumers and markets. We assume that ε_{ijmt} follows a generalized extreme value distribution allowing correlations across products. Specifically, we group products into three nests (smartphones, feature phones, and the outside option) and allow for correlations in ε_{ijmt} among products of the same nest. Let λ be the nested Logit correlation coefficient. We normalize the utility of the outside option to be $u^{h,l}_{i0mt} = \varepsilon_{i0mt}$.

Define the mean utility of product j for consumers of type (h,l) in market mt as

$$\delta_{jmt}^{h,l} = \rho^l + \beta X_j + \alpha^l(p_{jmt} - b_{jmt}^h(p_{jmt})) + Firm_{f(j)} + Time_t + Province_m + \xi_{jmt}, \quad (3.2)$$

and let

$$\mu_{ijmt}^h = \sigma_\alpha \nu_i (p_{jmt} - b_{jmt}^h(p_{jmt})). \quad (3.3)$$

Then, the utility function (3.1) can be written as $u_{ijmt}^{h,l} = \delta_{jmt}^{h,l} + \mu_{ijmt}^h + \varepsilon_{ijmt}$.

Let $\mathcal{J}_{gmt}$ be the set of products in market mt that belong to nest g, $G(\nu_i)$ denote the distribution of ν_i and $(\delta_{mt}^{h,l}, p_{mt})$ be the collection of $(\delta_{jmt}^{h,l}, p_{jmt})$ for all $j \in \mathcal{J}_{mt}$. The probability that a consumer of type (h,l) chooses product j of nest g in market mt is

$$s_{jmt}^{h,l}(\delta_{mt}^{h,l}, p_{mt}) = \int \frac{exp\{(\delta_{jmt}^{h,l} + \mu_{ijmt}^h)/(1-\lambda)\}}{D_g^\lambda (\sum_{g'} D_{g'}^{(1-\lambda)})} dG(\nu_i), \quad (3.4)$$

where

$$D_g = \sum_{j' \in \mathcal{J}_{gmt}} exp\{(\delta_{j'mt}^{h,l} + \mu_{ij'mt}^h)/(1-\lambda)\}.$$

We aggregate the above consumer type-specific market share function to obtain the product/province/time level market share as

$$\sum_{(h,l)} \tau_{mt}^{h,l} \; s_{jmt}^{h,l}(\delta_{mt}^{h,l}, p_{mt}), \quad (3.5)$$

where $\tau_{mt}^{h,l}$ is the population proportion of consumers of type h,l in market mt.

3.3.2 Supply Model

We describe the supply side by Bertrand competition. Firms with no eligible products solve a standard profit maximization problem, while firms with eligible products choose prices subject to the price ceilings of their eligible products.

Denote the product set of firm f by $\mathcal{J}_{fmt}$ and the set of its subsidized products by $\mathcal{J}^e_{fmt}$, and define $\boldsymbol{p}_{fmt} = (p_{jmt})_{j\in\mathcal{J}_{fmt}}$ to be the retail prices for firm f's products. We now rewrite the market share function in (3.5) as $s_{jmt}(\boldsymbol{p}_{fmt}, \boldsymbol{p}_{-fmt})$ where its dependence on $\delta^{h,l}_{mt}$ (and other factors) is absorbed in the subscription of the function jmt. Given the retail prices of the competitors in the market ($\boldsymbol{p}_{-fmt}$) and marginal cost mc_{jmt}, firm f chooses its prices $\boldsymbol{p}_{fmt}$ to maximize its profit:

$$\begin{aligned} &\max_{\boldsymbol{p}_{fmt}} \sum_{j'\in\mathcal{J}_{fmt}} (p_{j'mt} - mc_{j'mt})\ s_{j'mt}(\boldsymbol{p}_{fmt}, \boldsymbol{p}_{-fmt}), \\ &s.t.\ p_{j'mt} \le \bar{p}_{j't} \text{ for } j' \in \mathcal{J}^e_{fmt}. \end{aligned} \tag{3.6}$$

For a firm f without any eligible product, i.e., $\mathcal{J}^e_{fmt} = \emptyset$, the problem in (3.6) becomes an unconstrained optimization problem.

The optimality condition gives that

$$\sum_{j'\in\mathcal{J}_{fmt}} (p_{j'mt} - mc_{j'mt})\frac{\partial s_{j'mt}}{\partial p_{jmt}} + s_{jmt} = 0 \quad \text{for } j \notin \mathcal{J}^e_{fmt} \text{ or } p_{jmt} < \bar{p}_{jt}, \tag{3.7}$$

$$\sum_{j'\in\mathcal{J}_{fmt}} (p_{j'mt} - mc_{j'mt})\frac{\partial s_{j'mt}}{\partial p_{jmt}} + s_{jmt} \ge 0 \quad \text{for } j \in \mathcal{J}^e_{fmt} \text{ and } p_{jmt} = \bar{p}_{jt}. \tag{3.8}$$

In other words, for non-eligible products or eligible products with non-binding price ceilings, the equation (3.7) holds; for eligible products with binding price ceilings, however, the inequality (3.8) holds.

We assume the marginal cost to be

$$mc_{jmt} = \gamma X_j + Firm^s_{f(j)} + Province^s_m + Time^s_t + \omega_{jmt}, \tag{3.9}$$

where $Firm^s_{f(j)}, Province^s_m, Time^s_t$ are *supply-side* fixed effects at various levels and ω_{jmt} is the unobservable marginal cost shock.

We complete this section with a discussion about the bidding process. Due to the lack of data on the bids that firms submitted but did not win, we do not explicitly estimate the bidding process. To rule out the selection (on unobservable shocks) in the subsidy eligibility determined by the bidding process, we assume that marginal cost shocks are realized after the bidding process, i.e., the shocks are unobserved to firms when submitting their bids and to the evaluation committee when choosing winning bids. This timing assumption is reasonable because we include firm-, province- and time-specific fixed effects in the marginal cost specification, and thus the shocks are only product/region/time-specific transitory ones. Our estimation in Section 3.4 relies on this timing assumption.

3.4 Estimation

3.4.1 Demand Estimation

The demand estimation is similar to that in Berry et al. (1995). While there are four types of consumers who differ in preferences and subsidy eligibility and the (observed) overall market share is a weighted average of the (unobserved) type-specific market shares, we can extend the inversion results in Berry et al. (1995) to solve for the unobservable demand shocks ξ_{jmt} as a function of parameters and data.[2] Specifically, note that according to the definition of the mean utility in (3.2), the four mean utility values have the following relation:

$$\begin{aligned}
\delta_{jmt}^{NA,R} &= \delta_{jmt}^{A,R} + \alpha^R b_{jmt}^A; \\
\delta_{jmt}^{A,U} &= \delta_{jmt}^{A,R} + (\rho^U - \rho^R) + (\alpha^U - \alpha^R)(p_{jmt} - b_{jmt}^A); \\
\delta_{jmt}^{NA,U} &= \delta_{jmt}^{A,R} + (\rho^U - \rho^R) + (\alpha^U - \alpha^R)p_{jmt} + \alpha^R b_{jmt}^A.
\end{aligned} \tag{3.10}$$

[2]Berry et al. (2006) is an early application of the BLP framework to a case with (purely) discrete types of consumers. Kalouptsidi (2012) provides insights into the computation when there exist (a small number of) discrete types of consumers.

Using (3.10), we can define the market share function in (3.5) as

$$s_{jmt}(\delta_{mt}^{A,R}, p_{mt}, \tau_{mt}) = \sum_{(h,l)} \tau_{mt}^{h,l} \; s_{jmt}^{h,l}(\delta_{mt}^{h,l}, p_{mt}), \tag{3.11}$$

where $\tau_{mt} = (\tau_{mt}^{A,R}, \tau_{mt}^{NA,R}, \tau_{mt}^{A,U}, \tau_{mt}^{NA,U})$. (3.11) is a function of $\delta_{jmt}^{A,R}(s_{mt}, p_{mt}, \tau_{mt})$ but not the mean utilities of the other three consumer types, where s_{mt} denotes the collection of s_{jmt} for all $j \in \mathcal{J}_{mt}$. Equaling (3.11) to the market share in data s_{jmt} (for all $j \in \mathcal{J}_{mt}$), we can solve for the mean utility $\delta_{jmt}^{A,R}(s_{mt}, p_{mt}, \tau_{mt})$. Then we have the estimation equation as:

$$\begin{aligned} &\delta_{jmt}^{A,R}(s_{mt}, p_{mt}, \tau_{mt}) = \\ &\rho^R + \beta X_j + \alpha^R(p_{jmt} - b_{jmt}^A(p_{jmt})) + Firm_{f(j)} + Time_t + Province_m + \xi_{jmt}. \end{aligned} \tag{3.12}$$

Some taste parameters are allowed to differ across residence locations. However, our sales data are not residence-location specific, so the identification of such taste differences depends on the variation of rural/urban population proportions across provinces and time. Intuitively, consider two identical provinces except that the percentage of rural residents is higher in province A than in province B. If the market share of high-priced products (relative to that of low-priced ones) is smaller in province A than in province B, then such a data pattern indicates that rural residents are more sensitive to price than urban residents.

We estimate the demand parameters using the Generalized Method of Moments. The prices and market shares in the demand model are endogenous in the sense that they are correlated with ξ_{jmt}, the unobserved component of mean utility. The instrumental variables used in the demand estimation are as follows. First, following the literature, we have the BLP instruments constructed based on the characteristics of other products of

the same firm, or products of competing firms, or "close" products.[3] Second, since the differences between rural and urban tastes are identified by the population proportions of consumer types, our additional instrumental variables are the population proportions and their interactions with the BLP instruments. The market size used in the demand estimation is 10% of the population in the corresponding province and time, and our results are not sensitive to alternative market size measures.

3.4.2 Supply Estimation

The optimality conditions derived in Section 3.3.2 show that the equation (3.7) holds for non-eligible products or eligible products with non-binding price ceilings, and the inequality (3.8) holds for eligible products with binding price ceilings. Consequently, we can back out the marginal cost for some ("point identified") products, but there may be a set of marginal cost values that satisfy the optimality conditions for the other ("set identified") products. Our goals here are to back out the marginal costs for a subset of products and to estimate the marginal cost distribution for all products. In the counterfactual simulations in the next section, we use the estimated marginal costs for the "point identified" products; for the "set identified" products, we draw the marginal costs from the distribution.

Note that for an observation jmt, as long as its firm has any product j' in this market mt with binding price ceiling so that we have inequality (3.8) for $j'mt$, we cannot back out mc_{jmt} even if the equation (3.7) holds for this jmt itself. Therefore, we partition the observations by firm/market: (A) observations of firms without eligible products in the market: $\{jmt : \mathcal{J}^e_{f(j)mt} = \emptyset\}$; (B) observations such that some of the firm's products are eligible in the market but none of the corresponding price ceilings is binding: $\{jmt : \mathcal{J}^e_{f(j)mt} \neq \emptyset, p_{j'mt} < \bar{p}_{j't}, \forall j' \in \mathcal{J}^e_{f(j)mt}\}$; (C) observations such that at least one

[3]Following Gandhi and Houde (2019), two products in the same market are "close" in one categorical characteristic if the two products are in the same category, and "close" in one numerical characteristic if the difference between the two products is less than the standard deviation of that characteristic in that market.

product of its firm in the market is both subsidized and has a binding pricing constraint: $\{jmt : \exists j' \in \mathcal{J}^e_{f(j)mt} \ s.t. \ p_{j'mt} = \bar{p}_{j't}\}$.

For observations in both Samples (A) and (B), the equation (3.7) holds for all the products by the corresponding firm $f(j)$ in the market mt. Therefore, we can back out the marginal cost as

$$mc_{jmt} = p_{jmt} + [\Delta^{-1}_{fmt} \boldsymbol{s}_{fmt}]_{jmt}, \forall j \in \mathcal{J}_{fmt}, \tag{3.13}$$

where $\boldsymbol{s}_{fmt} = (s_{jmt})_{j \in \mathcal{J}_{fmt}}$, Δ_{fmt} is a $|\mathcal{J}_{fmt}| \times |\mathcal{J}_{fmt}|$ matrix whose (j, j') element is $\dfrac{\partial s_{j'mt}}{\partial p_{jmt}}$, for any $j, j' \in \mathcal{J}_{fmt}$.

For observations in Sample (C), there may be a set of marginal cost values that satisfy the optimality conditions because some conditions are inequalities. In general, the optimality condition (3.8) does not imply inequalities in the form of $\underline{c}_{jmt} \leq mc_{jmt} \leq \bar{c}_{jmt}$, where $\underline{c}_{jmt}$ and $\bar{c}_{jmt}$ are constants. Therefore, for observations in Sample (C), we can neither "solve" out marginal cost shocks from the first-order conditions nor easily construct bounds for them. Our approach is first to estimate the underlying distribution of the marginal cost. Then, for the observations whose corresponding marginal costs cannot be point identified, we draw marginal costs that are consistent with both the underlying distribution of marginal cost and the observed outcome as an equilibrium.

In this paragraph, we explain how to estimate the distribution of marginal costs. In the next paragraph, we explain how to draw marginal costs. Under the timing assumption explained at the end of Section 3.3.2, the distribution of marginal cost shocks conditional on Sample (A) (i.e., products of the non-eligible firm/market) equals the unconditional distribution: $F(\omega_{jmt}|jmt \in A) = F(\omega_{jmt})$. Therefore, we can estimate the distribution $F(\omega_{jmt})$ using observations in Sample (A). For observations in Sample (A), we plug in the backed-out marginal costs from (3.13) into the marginal cost specification (3.9) and estimate the marginal cost parameters $(\hat{\gamma}, \hat{Firm}^s_f, \hat{Province}^s_m, \hat{Time}^s_t)$ using the Generalized

Methods of Moments.[4] The estimated marginal cost shocks $\hat{\omega}_{jmt}$ for $jmt \in A$ are used to estimate the distribution $(\hat{F}(\omega_{jmt}))$. Note that although we can back out the marginal cost for observations in Sample (B), we do not use these observations to estimate the distribution because they are selected. These observations are from firms that price all subsidized products strictly below the price ceilings, a decision made after observing the marginal cost shocks.

To draw the marginal costs that are consistent with both the estimated underlying distribution of marginal cost and the observed outcome as an equilibrium, we proceed with the following steps. For each firm/market fmt with some observation(s) in Sample (C), we simulate draws of marginal cost shocks from the estimated distribution $\hat{F}(\omega_{jmt})$. Denote such a draw as $(\omega^r_{jmt})_{j \in \mathcal{J}_{fmt} \cap C}$ where $\omega^r_{jmt} \overset{i.i.d.}{\sim} \hat{F}(\cdot)$. We then compute the corresponding marginal costs as $\hat{\gamma} X_j + \hat{Firm}^s_f + \hat{Province}^s_m + \hat{Time}^s_t + \omega^r_{jmt}$ and verify whether these marginal costs satisfy all optimality conditions of this firm/market.[5] If not, we go back to the beginning of this paragraph and re-draw the marginal cost shocks until all the optimality conditions hold. We repeat this process for all markets with some observation(s) in Sample (C).

To sum up, the procedure for estimating the supply model (and conducting counterfactual simulations) is as follows:

Step (i). Estimate marginal costs for Samples (A) and (B) using first-order conditions (3.13) and demand estimates, and denote the results by $(\hat{\boldsymbol{mc}}_A, \hat{\boldsymbol{mc}}_B)$;

[4]We estimate the firm fixed effects for the 17 largest firms separately and a group of all other fringe firms. These 17 firms account for 93.33% of the observations.

[5]In practice, if we draw all marginal cost shocks for a market, it is nearly impossible that they will satisfy the equations in optimality conditions. So we draw shocks for the observations with binding constraints, compute the other shocks using the optimality equations, then take all drawn or computed shocks to verify the optimality inequalities.

Step (ii). Estimate marginal cost coefficients and marginal cost shocks ($\hat{\boldsymbol{\omega}}_A$) using Sample (A) only;

Step (iii). Use $\hat{\boldsymbol{\omega}}_A$ to estimate the empirical distribution of marginal cost shocks ($\hat{F}(\omega)$);

Step (iv). Draw marginal cost shocks for Sample (C), as explained above. Denote the corresponding marginal cost draws by $\boldsymbol{mc}_C^r, r = 1, ..., R$, where R is the size of Sample (C).

Step (v). Use $(\hat{\boldsymbol{mc}}_A, \hat{\boldsymbol{mc}}_B, \boldsymbol{mc}_C^r)$ to conduct counterfactual simulations.

3.4.3 Estimation Results

Table 3.2 reports the demand estimation results. We allow the coefficients on price and the constant term to be different between rural and urban consumers. The differences have the expected signs and are significant. Compared to urban consumers and all else equal, rural consumers are more sensitive to price (perhaps because of their lower average income). They are also more likely to purchase a cell phone (probably because fewer of them already own a cell phone). We allow for the random coefficient on price, but its estimated standard error is small and statistically insignificant. Consumers prefer an unsubsidized product, probably because the HAGC products are mostly low-end products on which consumers may have a bad impression. All the coefficients on favorable product characteristics are positive and significant as expected.[6] For example, to an average rural consumer, upgrading from a feature phone to a smartphone is equivalent to a price decrease by about 96 CNY.

Table 3.3 reports the marginal cost estimation results using the same instrumental vari-

[6]The continuous variables of characteristics, namely storage, rear camera resolution, and handset size, are normalized to have an absolute value between zero and one so that the magnitudes of their coefficients are comparable to those of dummy variables.

Table 3.2: Estimation Results on Demand

Variable	Est.	S.E.
Constant: Rural	-6.03*	(0.09)
Constant: Urban - Rural	-2.05*	(0.14)
Retail Price: Rural	-5.72*	(1.08)
Retail Price: Urban - Rural	4.91*	(0.22)
Price random coefficient std.	0.001	(0.72)
Being eligible for subsidy	-0.03*	(0.01)
Smartphone (v.s. feature phone)	0.55*	(0.02)
Include camera	0.84*	(0.05)
Include touch screen	0.27*	(0.01)
Support 3G network	0.23*	(0.01)
Dual SIM card	0.04*	(0.01)
Design: flip	0.47*	(0.02)
Design: slider	0.43*	(0.01)
Storage memory (normalized)	1.29*	(0.04)
Camera resolution (normalized)	2.83*	(0.11)
Handset size (normalized)	5.95*	(0.17)
Nested Logit coefficient	0.26*	(0.01)
Province, time, and firm dummies	Yes	

* p<0.01.

Table 3.3: Estimation Results on Marginal Cost

Variable	Est.	S.E.
Constant	-1.03*	(0.028)
Smartphone (v.s. feature phone)	0.32*	(0.005)
Include camera	0.55*	(0.003)
Include touch screen	0.005	(0.003)
Support 3G network	0.04*	(0.003)
Dual SIM card	0.04*	(0.003)
Design: flip	0.32*	(0.004)
Design: slider	0.33*	(0.004)
Storage memory (normalized)	0.18*	(0.014)
Camera resolution (normalized)	2.86*	(0.013)
Handset size (normalized)	3.33*	(0.062)
Province, time, and firm dummies	Yes	

* p<0.01.

ables as the demand estimation. We assume that firms maximize their profits from rural consumers rather than from all consumers for two reasons. First, according to industry analysis reports, the major firms focused on expanding their businesses in rural areas during the time of the data, partially in response to the HAGC program. Second, when we assume that a firm's objective function is a weighted average of profits as $w\pi_{rural} + (1-w)\pi_{urban}$, where π_{rural} (or π_{urban}) is the profit from rural (or urban) consumers, and estimate both marginal cost coefficients and w as an additional coefficient, we indeed obtain an estimate of w close to 1. Specifically, the estimate is $\hat{w} = 0.98$, and estimates of marginal cost coefficients are close to those in Table 3.3.[7] For these reasons, we assume $w = 1$ in the marginal cost estimation and the remainder of the chapter.

The estimation results show that marginal cost, as expected, is positively associated with all product characteristics and significantly so with most ones. The characteristics that consumers care about most, namely rear camera resolution and handset size, also have the largest marginal cost coefficients.

3.5 Counterfactual Simulations

We conduct counterfactual simulations to quantify the welfare effect of the subsidy program and highlight the role of the program design to put downward pressure on prices, i.e., the price ceilings and the eligible product set.

In each simulation, we draw marginal cost shocks as described by Step (iv) in Section 3.4.2, solve for the new pricing equilibrium for each market, and compute the corresponding government subsidy payment, consumer surplus, and producer surplus.[8] We report the average across simulation draws. We use the bootstrap method for standard errors. Specifically, we repeat the above process for different draws of the model coefficients from

[7]In this specification, the weight w is identified by rural population proportion variations across markets.

[8]The way to calculate consumer surplus in our setting can be found at Kohli and Daly (2006).

the estimated distribution.

We conduct three counterfactual simulations where the subsidy rate for eligible purchases is the same as in the data, i.e., 13% of the retail price but up to a maximum subsidy of 130 CNY. Table 3.4 summarizes the counterfactual designs. In the first counterfactual simulation (CF1), we simulate what would have happened if there were no subsidy at all. The comparison of such simulation results to the data gives us the overall effect of the HAGC subsidy program, i.e., the subsidy combined with firms' competition for subsidy eligibility, which restricts the subsidy to a set of eligible products and leads to a price ceiling for each eligible product. In the second counterfactual simulation (CF2), we simulate what would have happened if the same set of products as in the data were eligible for subsidy but there was no pricing ceiling. Comparing the outcomes from CF2 and those according to data allows us to quantify the effect of price ceilings. In the third counterfactual simulation (CF3), we simulate the effect of an alternative program where there is no competition for eligibility at all, i.e., all products were eligible for the subsidy and there was no price ceiling. The comparison of its results to those of CF2 informs us about the effect of enlarging the set of eligible products (to all products).

Table 3.4: Counterfactual Simulations

Counterfactual	Eligible product set	Price ceilings	The comparison v.s. CF1 gives the effect of ...
Data	Actual	Actual	subsidy + eligible set + ceiling
CF1	None	None	
CF2	Actual	None	subsidy + eligible set
CF3	All	None	subsidy

Table 3.5 reports the price effects. We divide the simulated equilibrium price of each observation by the price of the same observation in the case with no subsidy (i.e., CF1) to compute the percentage change. We then take the average across all draws of model coefficients and marginal cost shocks. We report the average across all observations within

three different groups (i.e., observations for ineligible products, eligible products without binding constraints, and eligible products with binding constraints) corresponding to Columns (1) - (3). The first row gives us the effect of the HAGC subsidy program. We can see that this subsidy program with firms' competition for subsidy eligibility leads to a reduction in price for some products while an increase for other products. Compared to a scenario without subsidy, the prices of the eligible products with binding price ceilings in the data are 9.46% lower on average (Column (3)) while other products' prices increase on average (Columns (1) and (2)). Intuitively, when consumers are eligible for subsidies, demand shifts to the right, and consequently, firms are likely to raise prices. The opposite effect for some products indicates that the competition for eligibility provides an incentive for firms to submit "competitive" price ceilings and thus dampens the price increases arising from the subsidy. We can also see this dampening effect by comparing the first row to the middle row, where we remove the price ceilings and find higher prices for all products. For example, without price ceilings, the price change for products in Column (3) moves from -9.46% to 3.25%. Because prices are strategic complements, the price ceilings (as a result of the competition for eligibility) not only lower the prices of the eligible products (Columns (2) and (3)) but also (slightly) reduce the prices of ineligible products (Column (1)). For the same intuition, when the subsidy program applies to all products without price ceilings, the prices increase even more (the last row). To sum up, the eligibility competition mitigates price increases due to the subsidy and even leads to a reduction in prices for some products (compared to the prices without the subsidy program).

Table 3.6 reports the welfare effects. Column (1) reports the total government subsidy payment amount. Columns (2)-(6) present consumer and producer surplus changes and their ratios to the total subsidy amount (Column (1)). Column (7) on $\Delta CS/(\Delta CS + \Delta PS)$ shows how the welfare change is split between consumer surplus and producer surplus.[9]

[9]See Appendix C for the discussion on additional alternative program designs and welfare measures.

Table 3.5: Price Changes (%) Compared to the Case without Subsidy

The effect of ...		(1)	(2)	(3)
Subsidy + eligible set + ceiling	(Data - CF1)	0.06	4.69	-9.46
		(0.21)	(3.26)	(4.29)
Subsidy + eligible set	(CF2 - CF1)	0.07	4.71	3.25
		(0.22)	(3.28)	(2.02)
Subsidy	(CF3 - CF1)	2.39	4.87	3.35
		(3.12)	(3.54)	(2.06)

Each column is the average across the following observations based on their status in the data, i.e., under the actual HAGC subsidy program. Standard errors are reported in parentheses.
(1): the observations for ineligible products;
(2): the observations for eligible products with no biding constraints;
(3): the observations for eligible products with biding constraints.

From the first row, we can see that the HAGC subsidy program increases the overall consumer surplus by 3.17 billion CNY, and the subsidy-eligible consumers are 3.76 billion CNY better off (Column (5)). However, the subsidy-ineligible consumers are 0.59 billion CNY worse off (Column (6)). This result is consistent with the price change pattern shown in Table 3.5. Even though firms' competition for subsidy eligibility mitigates the price increases arising from the subsidy, the prices of many products increase due to the subsidy program, leading to a decrease in the consumer surplus of ineligible consumers. In the end, both the overall consumer surplus and producer surplus increase, with 53% of the total surplus increase going to consumers (Column (7)). Moreover, the sum of consumer and producer surplus increases outweighs the subsidy amount: the total surplus increase is 129% of the total government subsidy payment. Therefore, under the assumption that the program leads to a tax increase and the welfare cost of raising 1 CNY tax revenues is lower than 0.29 CNY, there is a total welfare gain in the economy under the HAGC subsidy program.

In contrast, when price ceilings are removed (in the middle row), consumers, both the subsidy-eligible and ineligible ones, are worse off (Columns (4) to (6)) while producers are better off (Column (2)), compared to the first row. As a result, the ratio $\Delta CS/(\Delta CS + \Delta PS)$ reduces to 49%, indicating that the price ceilings component of the competition

for eligibility mitigates the pass-through of subsidy from consumers to firms.

The last row shows that a hypothetical subsidy to all products without the competition for eligibility would result in large increases in all welfare measures (except for the ineligible consumers due to the price increases). However, the total government subsidy payment would be 28.27 billion CNY, more than six times the payment under the actual HAGC subsidy program (4.61 billion CNY). This result indicates that specifying a set of eligible products may be necessary for making the subsidy financially feasible.

In summary, this chapter quantifies the welfare effect of the HAGC consumer subsidy program and the role of firms' competition for subsidy eligibility. We develop an estimation procedure that works with multiple consumer types and binding pricing constraints. Through a set of counterfactual simulations, we find that the eligible product set and the price ceilings, two critical components of the competition for eligibility, mitigated the price increase under subsidy and benefited consumers and society while limiting the required government subsidy payments.

Table 3.6: Welfare Changes Compared to the Case without Subsidy

The effect of ...	(1) Subsidy Payment	(2) ΔPS $+\Delta CS$	(3) ΔPS	(4) ΔCS	(5) ΔCS^A	(6) ΔCS^{NA}	(7) (4)/(2)
Subsidy + eligible set + ceiling	4.61	5.94	2.77	3.17	3.76	-0.59	53%
(Data - CF1)	(0.13)	(0.24)	(0.07)	(0.27)	(0.19)	(0.08)	
		129%	60%	69%	81%	-13%	
		(1.76)	(2.47)	(4.10)	(2.30)	(2.05)	
Subsidy + eligible set	4.60	5.84	2.95	2.88	3.55	-0.67	49%
(CF2 - CF1)	(0.13)	(0.25)	(0.09)	(0.32)	(0.22)	(0.10)	
		126%	64%	62%	77%	-14%	
		(2.16)	(3.26)	(5.33)	(3.03)	(2.48)	
Subsidy	28.27	37.33	10.31	27.03	29.13	-2.11	72%
(CF3 - CF1)	(1.54)	(1.94)	(0.58)	(1.97)	(1.70)	(0.31)	
		132%	37%	96%	103%	-8%	
		(1.40)	(2.74)	(2.50)	(1.55)	(1.43)	

The unit of absolute numbers in white background color is billion CNY. The percentages in gray background color are the ratio of the welfare change in each column to the corresponding government subsidy payment amount in Column (1). In parentheses are the standard errors, in either billion CNY or percentage point. "A" in Column (5) stands for the eligible consumers with agricultural Hukou, and "NA" in (6) for the ineligible consumers with non-agricultural Hukou.

Conclusion

This dissertation studies a consumer subsidy program where firms must compete to make their products eligible for the subsidy by committing to price ceilings on their products. The program we investigate is the Home Appliances Going to the Countryside program that subsidized consumers with the so-called agricultural Hukou in the Chinese home appliances and electronics markets, especially the cell phone market.

This dissertation first investigates the relation between the HAGC subsidy program and the ownership and recent purchases of home appliances and electronics, using the China Health and Nutrition Survey data. We find that households with agricultural Hukou had lower stock measures of home appliance ownership, but they had the higher flow measure as the number of products purchased in the past 12 months. We provide evidence that such a pattern is related to the HAGC subsidy program rather than merely a trend for households with agricultural Hukou.

Focusing on the cell phone category of the HAGC subsidy program and using the Chinese cell phone sales data, this dissertation shows the characteristics of winning firms, products, and price ceilings in the bidding process of the program and analyzes the relation between the HAGC program and the post-program sales, the number of competitors in the market, the average product age, and the upgrading to new technologies.

This dissertation also quantifies the program's welfare effect and emphasizes the role of the eligibility competition in shaping the welfare implications. To this end, an estimation procedure is developed to work with multiple consumer types and binding pricing constraints. The estimation and counterfactual simulation results show that the ex-ante competition mitigates the price increases arising from the subsidy and even leads to lower prices in some cases and that the subsidy program with ex-ante competition improves consumer and total surpluses while limiting the required government subsidy payments.

As a summary of the implications on subsidy policy designs, a consumer subsidy may improve the total welfare in an imperfectly competitive market, and imposing price ceilings may bring additional total welfare gain and let consumers take a larger share of the welfare gain.[10] However, the effect of a subsidy or tax in a specific market requires case-by-case quantitative empirical analysis beyond the general intuition above.

We close with a caveat of this dissertation. We do not model how firms strategically choose bids or how the bidding agency evaluates bids. This is because only winning bids, not losing ones, are observed. As a result, the bidding outcomes are taken as given when studying the post-bidding pricing under some timing assumptions, and the counterfactual simulations focus on the designs where the set of eligible products does not change endogenously. Other interesting alternative policies, such as changing the subsidy rate or revising the evaluation criteria, might change firms' bids. Other important aspects of the program's impacts, such as on market structure or innovation, would require the modeling and estimation of firms' responses to different policy designs. These topics are left for future research if the data on losing bids become available.

[10]While selecting a subset of products to subsidize may result in less overall welfare gain due to the distortion, it may improve the targeted consumers' surplus if the products preferred by the targeted consumers are selected and a higher subsidy amount is made feasible by such selection. See Appendix C.

Appendices

A Major Acquisitions in the Chinese Cell Phone Market

All the major acquisitions and mergers in the Chinese cell phone handset market were irrelevant to the market structure in our analysis of the HAGC program, which was launched at the end of 2007 and completely finished at the beginning of 2013.

On the one hand, some major consolidations happened either before or after the HAGC program period. TCL's acquisition of Alcatel's cell phone handset business was completed in May 2005 before the HAGC program. Microsoft's acquisition of NOKIA's cell phone handset business was completed in April 2014 after the program.

On the other hand, although a few other consolidations took place during the HAGC program, these consolidations would not change the definition of an individual firm in our models. Sony acquired Ericsson's 50% share in the joint venture known as "Sony Ericsson Mobile Communications" in February 2012, but neither Sony nor Ericsson had another cell phone handset business other than what was included in the acquisition. Google's acquisition of Motorola Mobility was approved in February 2012. However, all the Google-branded cell phone handsets before this acquisition were co-manufactured with HTC, Samsung, or LG, and these phones are all top-end products that are excluded

from the sample for the welfare analysis in Chapter 3. Please see Section 3.2 for the details about constructing the sample for analysis.

B Variable Definitions of Cell Phone Characteristics

Smartphone (v.s. feature phone): a dummy variable equal to 1 if this cell phone is a smartphone (instead of a feature phone).

Include camera: a dummy variable equal to 1 if a digital camera is integrated into the device.

Include touch screen: a dummy variable equal to 1 if a touch screen is integrated into the device.

Support 3G network: a dummy variable equal to 1 if this cell phone enables the third generation of wireless communication digital standards.

Dual SIM card: a dummy variable equal to 1 if this cell phone has more than one SIM card slot.

Flip design: a dummy variable equal to 1 if this cell phone has a flip, and the flip may include functions like microphone, keyboard, or camera.

Slider design: a dummy variable equal to 1 if this cell phone has an orientation where the keypad is not visible but needs to be pulled/pushed out to be revealed.

Storage memory (normalized): any device which contains fixed discs or flash memory (e.g., NAND, SDRAM) for storing (digital) data/information in gigabytes. Normalized

to the range [-1,1] by taking natural logarithm then dividing it by 10. Set to 0 if this cell phone is not a smartphone.

Camera resolution (normalized): the maximum resolution of the digital fixed image by the built-in camera in megapixels. Normalized to the range [-1,1] by taking natural logarithm then dividing it by 10. Set to 0 if no digital camera is integrated into the device.

Handset size (normalized): the diagonal length (the distance between opposite corners) of the device in inches. Normalized to the range (0,1) by dividing it by 10.

C Alternative Subsidy Policy Designs

This appendix explores several alternative subsidy policy designs that are not covered yet (because they are not directly about decomposing the overall welfare effect of HAGC).

In Chapter 3, we emphasize the (eligible) consumers' surplus gain from the HAGC program since the government aimed to help disadvantaged consumers. A natural question would be, what about the government making lump-sum transfers to the same targeted consumers rather than rebate their cell phone purchases? Note that the HAGC subsidy program also tried to support local firms to survive from the 2008 financial crisis and the shrink in exports, so the total welfare gain and the sales increase in the industry are also critical policy aims. As Chinese consumers are well known for saving a large proportion of disposable income for future needs, lump-sum income re-distribution would not effectively stimulate domestic consumption and help the local firms.

One may also consider a universal subsidy policy available to all products, which might not distort consumer preferences on competing products as much as the actual targeted (on selected products) subsidy. We have seen in Section 3.5 that such a universal subsidy at the actual 13% rate (of the retail price but up to a maximum subsidy of 130 CNY) would result in a huge subsidy payment that might not be financially feasible. Therefore,

we run additional counterfactual simulations for a hypothetical universal subsidy at a 2% rate instead, which turns out to imply an average total subsidy payment (4.67 billion CNY) very close to that under the actual policy (4.61 billion CNY).[11]

Table C.1 adds its last rows to Table 3.6 to show the results of the counterfactual simulations mentioned above. Table C.1 also adds its Columns (7) to (10) to show the welfare changes for different subgroups of consumers by both Hukou (and thus subsidy eligibility) and residence location. The results indicate that the hypothetical 2% universal subsidy would bring higher overall consumer surplus gains than the actual policy.

However, as we discuss in Section 1.4 and as the name "Home Appliances Going to the Countryside" implicates, the HAGC subsidy program aimed to help consumers from rural areas with relatively low income despite that the subsidy eligibility was based on Hukou type as a proxy of rural residence. The further breakdown of consumer surplus reveals that the consumers with agricultural Hukou in the rural area, the real target of the HAGC subsidy program, would have larger welfare gain under the actual program (1.53 billion CNY) than under the hypothetical 2% universal one (0.85 billion CNY), and the difference is significant at 5% level. Such results are not surprising since the government selected the products that best met the needs of targeted consumers and was able to offer the 13% (much higher than 2%) subsidy rate by restricting to a smaller range of eligible products.

Therefore, which policy design is better depends on the government's objective function. For example, suppose the government puts large enough weight on the welfare of consumers with agricultural Hukou in the rural area. In that case, it should choose the actual policy design with selected eligible products (together with a higher subsidy rate and price ceilings) over the hypothetical 2% universal one according to our simulation

[11] We find out the rate to be about 2% by trying different subsidy rates and comparing the implied subsidy payment amount to that under the actual policy. Here we suppose only consumers with agricultural Hukou are eligible for the subsidy, the same as in the real world.

results.[12]

[12]There are some other operational reasons (that are not in the scope of our economic analysis) for not expanding the subsidy to all products. For example, the government did quality examinations on each participating cell phone model to ensure it would meet the needs of eligible consumers, which would be less practicable for all the thousands of models. Limiting the set of eligible products also made it easier for the government to prevent abuse and fraud in the rebate redemption.

Table C.1: Welfare Changes Compared to the Case without Subsidy (Cont.)

The effect of ...	(1) Subsidy Payment	(2) ΔPS $+\Delta CS$	(3) ΔPS	(4) ΔCS	(5) ΔCS^{A}	(6) ΔCS^{NA}	(7) $\Delta CS^{A,R}$	(8) $\Delta CS^{A,U}$	(9) $\Delta CS^{NA,R}$	(10) $\Delta CS^{NA,U}$
Subsidy + eligible set + ceiling	4.61	5.94	2.77	3.17	3.76	-0.59	1.53	2.23	-0.06	-0.54
(Data - CF1)	(0.13)	(0.24)	(0.07)	(0.27)	(0.19)	(0.08)	(0.17)	(0.05)	(0.01)	(0.07)
		129%	60%	69%	81%	-13%	33%	48%	-1%	-12%
		(1.76)	(2.47)	(4.10)	(2.30)	(2.05)	(2.86)	(1.70)	(0.19)	(1.88)
Subsidy + eligible set	4.60	5.84	2.95	2.88	3.55	-0.67	1.40	2.15	-0.06	-0.61
(CF2 - CF1)	(0.13)	(0.25)	(0.09)	(0.32)	(0.22)	(0.10)	(0.19)	(0.06)	(0.01)	(0.09)
		126%	64%	62%	77%	-14%	30%	46%	-1%	-13%
		(2.16)	(3.26)	(5.33)	(3.03)	(2.48)	(3.34)	(1.50)	(0.21)	(2.28)
Subsidy	28.27	37.33	10.31	27.03	29.13	-2.11	6.57	22.57	-0.19	-1.92
(CF3 - CF1)	(1.54)	(1.94)	(0.58)	(1.97)	(1.70)	(0.31)	(0.83)	(0.94)	(0.02)	(0.29)
		132%	37%	96%	103%	-8%	23%	80%	-1%	-7%
		(1.40)	(2.74)	(2.50)	(1.55)	(1.43)	(1.75)	(2.05)	(0.11)	(1.33)
Subsidy at 2% rate	4.67	6.41	2.12	4.29	4.96	-0.67	0.85	4.10	-0.03	-0.64
(CF of universal 2% - CF1)	(0.06)	(0.30)	(0.07)	(0.27)	(0.19)	(0.09)	(0.10)	(0.10)	(0.00)	(0.08)
		137%	45%	92%	106%	-14%	18%	88%	-1%	-14%
		(4.70)	(1.17)	(4.73)	(2.84)	(2.01)	(1.81)	(1.62)	(0.08)	(1.93)

The unit of absolute numbers in white background color is billion CNY. The percentages in gray background color are the ratio of the welfare change in each column to the corresponding government subsidy payment amount in Column (1). In parentheses are the standard errors, in either billion CNY or percentage point. Columns (5) - (10) are surplus gains for different subgroups of consumers, where "A" stands for agricultural Hukou, "NA" for non-agricultural Hukou, "R" for rural, and "U" for urban.

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